# Legibility of Alphanumeric Characters and Other Symbols

## II. A Reference Handbook

United States Department of Commerce
National Bureau of Standards
Miscellaneous Publication 262-2

UNITED STATES DEPARTMENT OF COMMERCE • John T. Connor, *Secretary*

NATIONAL BUREAU OF STANDARDS • A. V. Astin, *Director*

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D. Y. Cornog and F. C. Rose

Institute of Applied Technology
National Bureau of Standards
Washington, D.C.

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## Contents



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# LEGIBILITY OF ALPHANUMERIC CHARACTERS AND OTHER SYMBOLS: II. A REFERENCE HANDBOOK

D. Y. Cornog and F. C. Rose

The major psychological findings and data in the field of the legibility of alphanumeric characters and other symbols are provided in this detailed Reference Handbook. Summaries and extracts of information for 203 experimental, developmental, review, and other legibility reports are presented and are multiply indexed in depth by (1) a matrix, cross-reference index (article versus functional variables - environmental typographical), (2) author indexes (alphabetical and chronological), and (3) a character-face-name index. These Handbook entries are further indexed by the permuted title index in NBS Miscellaneous Publication No. 262-1, "Legibility of Alphanumeric Characters and Other Symbols: I. A Permuted Title Index and Bibliography." Selected samples of several important experimental and other faces are presented in an appendix. Key words: Alphanumeric Characters, Displays, Handbook, Human Factors, Legibility, Psychology, Readability, Standards, Symbols, Type Faces, Typography, Visibility.

## INTRODUCTION

This Reference Handbook is the second of several related reports on the subject of the legibility of alphanumeric characters and other meaningful symbols. It is designed as a reference source to the information contained in the primary human factors and psychological technical and scientific legibility literature. A preceding report, Legibility of Alphanumeric Characters and Other Symbols: I. A Permuted Title Index and Bibliography, NBS Miscellaneous Publication No. 262-1, serves as an index-key and bibliography to the human factors legibility literature. A selection of materials from the bibliography of Part I serves as the basis for the information presented in this Handbook (Part II). It is intended that these first two reports should be used in conjunction with one another, but each is complete in itself.

The Legibility Project of the Research Information Center and Advisory Service on

Information Processing (RICASIP) is producing the series of legibility reports, including the Reference Handbook. RICASIP is part of the Information Technology Division, Institute for Applied Technology, National Bureau of Standards (NBS), and has been jointly sponsored by NBS and the National Science Foundation. The legibility research of RICASIP is especially directed toward those people interested in information processing problems and those areas of information selection and retrieval in which the human acceptability of machine printouts and various displays of document identification, abstracts, and text is clearly related to questions of legibility. Closely related are the problems involved in the design of characters and symbols developed for automatic character recognition, and also the development of standards and specifications for printing, including automatic photocomposition techniques.

In the legibility literature, there is much confusion and overlap in the usage of the terms legibility, readability, perceptibility, and visibility. For the purposes of this Handbook, the term legibility is considered to include these and any closely related concepts. In general, legibility refers to the characteristics of printed, written, or other displayed meaningful symbolic material which determine the speed and accuracy with which the material may be read or identified. In using the Handbook information, note should be made of the "legibility" usage of each experimenter. The psychological literature on perception has been included only when it was closely involved with the specific problems of alphanumeric characters and other meaningful symbols. "Other symbols" include such items as the arrows and other coded symbols used to present information on radar displays. Studies concerned only with environmental variables, i. e. illumination and symbol-background contrast, and the legibility of dials and scales have received little attention.

Other criteria for inclusion or rejection of material for the Handbook include (1) emphasis on post-1940 information, and (2) emphasis on psychological, quantitative experimentation, as contrasted with artist-designer information based primarily on opinion of and experience with aesthetic considerations and acceptability. The literature coverage is primarily from the United States, but a few foreign entries are included. Access to the foreign literature was chiefly through secondary reference sources.

The entries contained in this Reference Handbook represent only a fraction of the material covered in studying the problems of legibility. For a particular article to have been included, it was judged to have a substantial degree of pertinency for legibility in terms of the various criteria discussed in this introduction. Thus, the Handbook contains

a selective, rather than an exhaustive, coverage. The degree of individual article coverage varies from article to article, depending mostly upon the length of the original document and, to a lesser extent, upon the abstractor's subjective evaluation of the article's relative importance in meeting the selection criteria for the Handbook.

It is intended that the person using the Handbook will be able to ascertain from it whether or not it would be of value to him to go to the original source of information in order to determine more complete details of experimental procedures, results, and conclusions.

Accession numbers at the beginning of each citation (upper-left corner) and the Document Extract "author-date" method of identification (e.g. Craik-1943, Paterson-1947a, etc.) have been carried forth from the Permuted Title Index and Bibliography (NBS-MP-262-1). Since the inclusion of literature in this Handbook represents only a selection from 262-1, an author's second article for a particular year may be included (e.g. Berger-1944b), while the first (Berger-1944a) has been omitted. Also, the citations include several abbreviations and numbers that need further explanation. Contract numbers, for U.S. material, refer to U.S. Government military and other agency contracts. Numbers prefixed by AD-, ATI-, and TIP-, are accession numbers assigned by the Defense Documentation Center, Cameron Station, Alexandria, Virginia 22314, and are available from them at no cost to those who are affiliated with the Department of Defense. For others, the same reports are available from the Clearinghouse for Federal Scientific and Technical Information, Sills Building, 5285 Port Royal Road, Springfield, Virginia 22171. AMEL (Aero-Medical Equipment Laboratory) is part of the U.S. Navy. WADC (Wright Air Development Center---later WADD, . . . Division), ESD (Electronic Systems Division), RADC (Rome Air Development Center), and AFCCDD (Air Force Command and Control Development Division) are all part of the U.S. Air Force.

Access to the abstracts may be made through (1) the Permuted Title Index and Bibliography (NBS-MP-262-1), (2) the Author Indexes (alphabetical and chronological) in Appendix A, (3) the Character Face Name Index (Appendix B), and (4) the Matrix Subject Index (rear fold-out). Appendix D, a Glossary and explanation of the subject terms used in the Matrix Index, will be found of use in conjunction with the Matrix.

The contribution of Mrs. Betty Anderson in the editing and typing of the manuscript has been invaluable. The staff of the Information Processing Reference Service, a part of the Information Technology Division, NBS, provided bibliographic support.

* * *

REFERENCE INFORMATION EXTRACTS

3423 Aldrich-1937

Aldrich, Milton H.
Vermont U., Burlington
PERCEPTION AND VISIBILITY OF AUTOMOBILE LICENSE PLATES
In PROCEEDINGS OF THE SEVENTEENTH ANNUAL MEETING,
1937, Washington, D. C., Highway Research Board,
Vol. 17, p. 393-412

Problem: Determine the effect of number, grouping, style, and stroke-width of digits, on the legibility of numeric characters to be used on automobile license plates. Also consider the effect of introducing one or more alphabetic characters into the legend. The author notes that "(t)he intrinsic legibility of a license plate will depend upon the combined effect of the following items:

1. "Size and shape of plate.
2. "Height and width of characters.
3. "Style and width of stroke of characters.
4. "Spacing and grouping of characters.
5. "Color combination.
6. "Amount of gloss on the figures and background.
7. "Area ratio of legend to background.
8. "Content and arrangement of the items on the plate.
9. "Number of characters in the legend.
10. "The letters selected for use in combinations.
11. "The number of letters used in the legend.

"External conditions which will also affect the legibility are:

1. "Distance of the observer from the plate.
2. "Angle at which observer views plate.
3. "Intensity and color of plate illumination.
4. "Angle at which most of the light strikes the plate.
5. "Conditions of vehicle movement (i. e., stationary, slow or high speed, receding or approaching, smooth or rough road, etc.)
6. "Amount of dirt or moisture on the plate.
7. "Atmospheric conditions.
8. "Position of the plate on the vehicle.
9. "Amount of dust which is thrown up by the car, or by passing traffic.

"Many of these later items are beyond the control of the plate designer." (p. 393-394)

Procedure: "Perception" and "visibility" tests were performed. The "perception" tests "compare(d) the merits of the plain numeral and the various letter-numeral systems grouped in different ways. The effect of using letters the same size, or either larger or smaller than the numerals in the group, was experimented with." (p. 394) Thus, 50 subjects (mostly students) individually viewed 50, black-on-white, 2-inch high, alpha-numeric character groups at an "easily visible" distance. Each group was exposed for 0.67 seconds. Groups presented are as follows (not in the type face used by investigators):

| | | | | | |
|---|---|---|---|---|---|
| 36.286 | P.284.J | 683<br>869 | 68LF4 | 284.PJ | 514<br>076 |
| F48392 | T 385<br>D | J608 | 60J8 | 16.52937 | LZP.047 |
| 593.652 | 514.076 | 1306<br>536 | 468.053 | 329E | 59.36.52 |
| DQ.953 | 3E29 | | 193.JQC | 683.869 | TD385 |
| 1.652.937 | | | 1686<br>398 | 68.723 | |

| | | | | | |
|---|---|---|---|---|---|
| 68LF4 | 59PV6 | 9E. 27. 04 | D. 953. Q | I 426 | 1306. 536 |
| 306. 829 | 1686. 398 | 19. 36573 | 698. 968 | B | 4F. 83. 92 |
| LZP | 9ZT63 | IB. 426 | HQF | 1936. 573 | 306829 |
| 047 | HQF. 493 | 698968 | 493 | 9ZT63 | 59PV6 |
| 46. 80. 53 | | JQC. 193 | | | E92704 |

(above from p. 398)

Accuracy was the test criterion. In the "visibility" tests, 14 subjects viewed 10, black-on-white, numeric character groups. Groups consisted of five to six, 3-inch high, 1-1/4- to 1-1/2-inch wide, 1/4- to 3/8-inch stroke-width, 1/2-inch spaced digits in the ROUND, BLOCK, OPEN, and VERMONT 1937 styles. Stimuli were viewed outdoors, under varying weather conditions, and at a distance of 200 feet or less (in 10 foot increments) until the legibility threshold was reached for individual digits. In the order displayed, digit groups were in the following layout (style/width (inches)/stroke-width (inches) ):

| | | | | | |
|---|---|---|---|---|---|
| ROUND | 1-1/2 | 3/8 | OPEN | 1-1/2 | 3/8 |
| OPEN | 1-1/2 | 1/4 | OPEN | 1-1/2 | 1/4 |
| OPEN | 1-1/2 | 3/8 | VERMONT 1937 | 1-1/4 | 3/8 |
| BLOCK | 1-1/2 | 3/8 | ROUND | 1-1/2 | 3/8 |
| ROUND | 1-1/2 | 1/4 | BLOCK | 1-1/2 | 1/4 |

(above from p. 405)

Some variants of individual digits were introduced.

Result: From the "perception" tests, the following results and conclusions were derived:

1. One disadvantage in the use of alphabetic characters (when mixed with numerics) on auto license plates is that, if one character is missed in an attempt to read the number of a retreating car, the car may be traced as one of ten if it is known that numerics only are on the plate, but as one of 34 if alpha-numerics are present.
2. Combinations of 5 characters were better than 6, which in turn were better than 7. The striking difference was between 6 and 7.
3. "The presence of letters in the group increases the difficulty of perception, this difference increasing with the number of letters appearing." (p. 404)
4. There was a slight preference for grouping characters by three's rather than two's, but both were superior to the equal spacing of all characters.
5. In 6-character groups containing 1 letter, the preference was for grouping by two's rather than separating the letter only from the numerics.
6. In 5-character groups containing 2 letters, there seemed to be a very slight preference for the groups in which the letters and numerals were placed in separate groups.
7. Contrasting letters from numerals by making the former smaller "did not aid in the perception of the number." Therefore, "the letters should be . . . at least as large as the numerals." (p. 404)
8. "Some advantage in perception seems to be gained with 6 and 7 character" (p. 404) groups when a "Devine" system (over and under) of grouping was employed. There was no advantage for groups totaling less than 6 characters.
9. "No extensive investigation on letter confusion seems to have been made, but Dr. Lauer says the letters A, F, H, K, M, R, S, U, W, X, Y, and Z appear to be best." (p. 405)

From the "visibility" tests, the following results and conclusions were derived.

1. "No appreciable difference . . . (was) found between the ROUND and BLOCK styles." (p. 406) However, "the OPEN type numerals (were) more visible than either" (p. 409) of the above.
2. The digit "1" was legible at a farther distance with a base than without. However, "the top should be small lest this digit be confused with '7'." (p. 410)

3. The rounded "3" also was legible at a farther distance than the flat top "3", although this may have been because the latter was frequently confused with the "5".
4. There was a very small superiority (in all cases) of the 3/8- over the 1/4-inch stroke-width. "The optimum stroke doubtless would vary with the style, height, and width of the numerals, the ratio of height to width, and possibly other factors. It is a question which could well be investigated further." (p. 408)
5. ". . . 3- by 1-1/2 (-inch) numerals (were) quite superior to 3- by 1-1/4 (-inch) numerals." (sic) (p. 409)
6. Little confusion resulted from the digits 1, 4, 5, 6, 7, and 0. Except for the BLOCK "2" (which was not confused at all), the digit "2" was sometimes confused with 1, 3, 5, 7, and 8. The rounded "3" was infrequently confused, except in the VERMONT 1937 numerals, wherein it was given frequently as 1 or 7. The digit "8" was frequently confused with 9, although use of "the OPEN style '9' should tend to reduce this confusion." (p. 409) Use of the OPEN type 5 and 6 should help in other confusion areas. The digit "9" was most frequently confused, being given as 5 or 8, and, with "the narrow VERMONT numerals, . . . also . . . as 1, 7, and 0." (p. 409) The fact that "9" was most frequently confused and "6" was one of the least frequently confused may possibly be attributed to "the fact that most cues in reading are secured from the upper half of the . . . characters." (p. 409) Thus, "since it is hardly feasible to omit any digit even though it may be confused frequently, numerals should be designed to emphasize their distinguishing characteristics." (p. 410)
7. While "no comparisons of legibility due to spacing can be made" (p. 409) from this experiment, the author again refers to Dr. Lauer as saying that " 'greater spacing between the numbers would greatly increase their legibility. . . (and that) letters should not center closer than 2 (inches).' " (p. 409)
8. "(D)igits in the end positions . . . were more legible than . . . elsewhere." (p. 409)

The author closes with general comments on plate borders and state/year designation locations. Comments on this work, by Dr. A. R. Lauer (in an appended discussion) concern the following:

1. "(I)f the stroke gets much larger than 3/8-(inch), there is a tendency for the number or letter to blur." (p. 412)
2. "We found (state identifications at the bottom) a decided advantage over vertical state identifications. . . (because in the latter) . . . the small letters tended to run together and resemble a letter I or number 1." (p. 412)
3. "(A)nything at the top of the . . . plate is likely to reduce . . . perception of the number . . . ." (p. 412) (See item 6 of "visibility test" results above.)
4. "(C)olor combinations of the plates are of even more importance than the shape of letters or numbers, and slight differences in illumination which it is possible to throw upon them." (p. 412)

* * *

3424 Allen-1955

Allen, Terrence M. and Straub, Arthur L.
Virginia Council of Highway Investigation and Research, Charlottesville
SIGN BRIGHTNESS AND LEGIBILITY
In NIGHT VISIBILITY 1955, Highway Research Board Bulletin 127, (Washington, D. C., National Academy of Sciences-National Research Council Publication 415, 1956), p. 1-14, 23 refs.

Problem: "Four factors of primary importance to the night legibility of signs are sign

brightness, the level of illumination to which the eye is adapted, characteristics of letters, and contrast direction (black letters on white or vice versa). . . These factors were investigated in a field . . . and a laboratory experiment to gather information on the(ir) effects . . . and . . . interrelationships . . . ." (p. 1)

Procedure: The authors first present a review of the literature on the legibility of reflectorized signs. Then, in the first experiment (field study), eight subjects (25-30 years old and with 20/25 to 20/15 visual acuity) were used in investigating (1) four levels of sign reflectance (white paint, beads on paint, moderately reflective sheeting, and highly reflective sheeting), (2) two conditions of background illumination (incident night lighting from street lamps, buildings, and other cars versus only the headlamps of the test car), and (3) high and low headlamp beams. "(S)ubject(s) rode beside the driver as the test car approached the sign (which contained two 7-inch high, BPR (Bureau of Public Roads) SERIES C digits) at a constant speed of 10 (miles per hour)." (p. 4) In the second experiment (laboratory investigation), "(f)our factors were selected as the most fruitful for investigation: sign brightness (0.1, 1.0, 10, and 100 foot-lamberts), surrounding illumination (0.001 and 0.1 foot-candles at the subject's eyes), letter series (BPR SERIES A, B, C, D, E, and F capitals) and contrast direction (white-on-black versus black-on-white)." (p. 6) In this experiment, 19 subjects (20-35 years old and with 20/25 to 20/17 visual acuity) viewed slides of sample messages projected onto a screen.

Result: In the field experiment, all factors (except surrounding illumination) and "(a)ll interactions of the factors tested were significant." (p. 4) And, of all these, only reflectances by surrounding illumination by headlight beams, and surrounding illumination by headlight beams (both of which were at the 5 percent level) were not significant at the 1 percent level of confidence. "For high beams, however, increases in reflectance beyond 'beads on paint' yielded no increase in legibility distance. In fact, results showed a slight decrease and the high-reflectance sign was read at a greater distance with low beams than with high beams." (p. 4) In the laboratory experiment, "(s)tatistical analysis of the results . . . show(ed) . . . (s)ignificant factor interactions . . . as follows: (1) Brightness x Illumination, (2) Brightness x Contrast Direction, and (3) Brightness x Letter Series. . . This means that results for illumination, contrast direction, or letter series were different depending upon the level of brightness. . . The following subject interactions were significant: (1) Brightness . . . , (2) Illumination . . . , (3) Brightness x Illumination . . . , and (4) Contrast Direction . . . (p. 10) The results of this (laboratory) study have not yet been validated in the field or related to reflective materials. However, from the relationships observed . . . , the following . . . conclusions are made . . . :

1. "Surrounding illumination is . . . important . . . in relation to reflective materials. In a brightly-lit area, higher sign brightness is needed for legibility, and . . . is permissible without excessive irradiation. High-reflectance signs on a dark open road may have poor legibility because of irradiation.
2. "Letter size is a very important factor, since it determines effective sign brightness. Large letters can be read at distances where illumination from headlights is low, if sign reflectance is high. Small letters, however, must be read at distances where illumination from headlights is high. In this case, high sign reflectance may produce excessive irradiation. . .
3. "(T)he wider letters with their wider stroke width are less severely affected by irradiation. However, these differences . . . are small compared to the differences in legibility distance. SERIES A letters must have about twice the letter height as SERIES F to have the same legibility distance and the same illumination from headlights. . .
4. "(W)hite letters on black gave superior legibility in the middle range of brightness, but results indicate that irradiation is more serious for white letters of the standard series. White-on-black signs may be very effective, but care should be used to achieve a well-designed sign." (p. 12)

* * *

2129 Alluisi-1957

Alluisi, Earl A. and Martin, Hugh B.
Laboratory of Aviation Psychology, Ohio State U.,
Columbus

COMPARATIVE INFORMATION-HANDLING PERFORMANCE WITH SYMBOLIC AND CONVENTIONAL ARABIC NUMERALS: VERBAL AND MOTOR RESPONSES

Apr 57, 12p.
Contract AF 33(616)-3612; Project 7192
WADC Technical rept. 57-196; AD-118 160

Problem: "(C)ompare the information-handling performance of subjects in making verbal (number-naming) and motor (key-pressing) responses to . . . (a) set of symbolic numerals . . . (generated from an EIGHT-ELEMENT STRAIGHT-LINE MATRIX) along with a set of conventional numerals (AND 10400)." (p. iii)

Procedure: In a two part experiment, 48 male student subjects were randomly divided into two groups of 24 for each part. In the motor response part, subjects responded, by means of finger-keys, to 1/4-inch high numerals (as defined above) back-projected onto a 10-inch diameter opal glass screen in the display of a Serial Discrimeter (sic) (designed and constructed by the Laboratory of Aviation Psychology, The Ohio State University). Numerals were presented in random sequence (but not inter-mixed) within sessions to subjects, who were seated 28 inches from the display screen. Broad-band noise, at approximately 70 decibels, was presented to subjects through earphones in order to mask extraneous sounds. Conditions for the second (verbal response) part of the experiment were the same as for the first part, except that subjects responded by speaking into a boom microphone. Speed and accuracy were the test criteria in both parts of the experiment.

Result: "On an a priori basis, it seemed reasonable to suppose that information-handling performance with the symbolic numerals might have at least equaled that with the conventional numerals. . . The data of the present experiment did not corroborate this supposition. . . (A)n interaction between the two types of numerals and the two modes of response . . . was . . . evidenced . . . . In terms of information handling (bits/second), time, and errors, performance with the conventional numerals was consistently superior to performance with the symbolic numerals when verbal responses were made. No such clear superiority for either set of numerals was evidenced in the motor-response performances." (p. 8) The former might be "(b)ecause number-naming responses to conventional Arabic numerals are greatly overlearned in our culture . . . A second line of argument would suggest that performance with straight-line and angular figures is superior to performance with conventional numerals only under difficult or threshold-like viewing situations in which probability of correct identification, and not response time, is measured. . . Both hypotheses . . . are consistent with the data." (p. 8-9) Furthermore, "if the increase in information-handling performance . . . represent(s) learning, then it was of a special type that result(s) in faster speed performance, but lower accuracy." (p. 9) And yet, "if learning was involved, it was probably not a form of learning related to the perception of the numerals . . . With regard to practical applications, the numerals formed by the use of an EIGHT-ELEMENT 'printing' MATRIX do not appear to be quite as satisfactory as standard AND 10400 numerals. They should not be used if other considerations are equal, but should their use be dictated by expediency the result should be only a small drop in information-handling performance." (p. 9-10)

Note: For the commercially published version of this work, see Alluisi-1958, following.

* * *

2130 Alluisi-1958

Alluisi, Earl A. and Martin, Hugh B.
Laboratory of Aviation Psychology, Ohio State U.,
Columbus
AN INFORMATION ANALYSIS OF VERBAL AND MOTOR
RESPONSES TO SYMBOLIC AND CONVENTIONAL ARABIC
NUMERALS
Journal of Applied Psychology, 42:2 (April 1958) 79-84

Problem: "(C)ompare the information-handling performance of (subjects) in making verbal and motor responses to two sets of Arabic numerals---one . . . conventional . . ., the other . . . symbolic figures drawn from an EIGHT-ELEMENT, STRAIGHT-LINE MATRIX." (p. 83)

Procedure: Key-pressing, motor responses and number-naming, verbal responses were made by two groups of 24 subjects each. The apparatus utilized was a Serial Discriminator, which for this study contained a 10-inch diameter, opal glass, display screen. "The various symbols were projected onto the screen from the back by means of a ten-unit optical projector, each unit of which contained a different photographic transparency . . . The scoring unit consist(ed) of . . . a timing . . . and an automatic recording element. . . The conventional numerals were the AND 10400 . . . The symbolic numerals were straight-line figures generated from an EIGHT-ELEMENT MATRIX . . . (as) illustrated . . . The symbols from each of the two sets appeared . . . as 1/4-(inch) high light patterns at the center of the display, approximately 28 (inches) in front of the seated (subject)." (p. 80)

Result: "When verbal responses were made, the conventional numerals were consistently superior in performance to the symbolic numerals. This was true whether performance was measured in terms of information handling (bits/second), time, or errors. No such clear superiority was evidenced for either set of numerals when motor responses were made. . . (The former) interaction . . . might be a stimulus-response compatibility effect resulting from use of the much-practiced ensemble of number-naming responses to conventional Arabic numerals. . . (A)lso . . ., performance with straight-line and angular figures should be superior to performance with conventional numerals under difficult or threshold-like viewing situations as, for example, in visibility studies, but not necessarily . . . under speeded-response conditions with stimuli above threshold. . . With regard to . . . applications, the . . . EIGHT-ELEMENT 'printing' MATRIX do(es) not appear to be quite as satisfactory as AND 10400 . . . (B)ut should their use be dictated by expediency the result should be only a small drop in information-handling performance." (p. 84)

Note: For the contract-report version of this work, see Alluisi-1957, preceding.

* * *

3323 AmASHO-1961

American Association of State Highway Officials, Washington, D.C.
MANUAL FOR SIGNING AND PAVEMENT MARKING OF THE
NATIONAL SYSTEM OF INTERSTATE AND DEFENSE HIGHWAYS
1961, 75 p.

Problem: "The National System of Interstate and Defense Highways, referred to as the Interstate System and now under construction along the Nation's principal travel desire

lines, was conceived and is being built primarily to provide rapid, convenient and safe travel between and through major traffic generating centers. Essential to the realization of these valuable benefits is a uniform system of highway signing and marking that will be fully adequate in an environment of high volume, high speed motor vehicle traffic on modern controlled access highways." (p. 7)

Procedure: "For (the above) reason, a new concept has been developed for signing the Interstate System." (p. 7)

Result: The Manual's Table of Contents, which is indicative of its mission, follows (if brief):

I. Introduction, including signing, uniformity, and standards.

II. General characteristics of signing, including messages and displays; overhead installations; lettering, spacing, and borders; color, reflectorization, and illumination; destination messages; arrows; and clearances.

III. Interchange signing, including layout; and advance guide, exit direction, gore, and other guide signs.

IV. Route markers, including application, design provisions, trail blazer installations, intersecting routes, cardinal direction and off-route markers, overlapping routes, and signing for memorial highways.

V-IX. Rest areas, signing for services, mileposts, regulatory and warning signs, and sign structures.

X. Miscellaneous considerations, including adjacent signing, placement for effective viewing, and sign materials.

XI. Other details of design and location, including letter height and arrow specifications, and individual sign designs.

XII. Pavement; including edge, and exit and entrance ramp; marking.

XIII. Delineators---location, application, design, performance, and median crossovers.

Typically, the figures shown are examples of signing, while the two tables concern (1) letter style and height for principal guide signs, and (2) delineator spacing on horizontal curves.

* * *

2132 Anderson-1960

Anderson, Nancy S., Braunstein, Myron and Novick, Lee

IBM Research Center, Yorktown Heights, N.Y.

AN EVALUATION OF HUMAN READABILITY AND RECOGNITION OF A SPECIALIZED FONT

Rept. no. RC-219, 11 Feb 60, 20p.

Problem: Evaluate the readability and recognition of E13B compared to BANKERS GOTHIC and each of these to a mixture of the two numeric fonts.

Procedure: Using the E13B and BANKERS GOTHIC fonts, New York college students participated in "transcription" and "recognition" experiments. The "transcription" experiment involved six subjects who were given a training period designed to have them develop a touch system on a ten-key adding machine. They were then each to read a ten-digit number (in one font) on a card and transcribe that same number to the machine, for a number of trials, until a speed/error plateau was reached. Each subject then repeated the experiment for the other font. Scoring was based on both speed and error rate of the first and last six trials. The "recognition" experiment involved 38 subjects who were each given a booklet of test pages containing ten-digit numbers in one font. The first occurrence of a specific single digit on a page was crossed out. The subject was to cross out all other occurrences of the same digit and count the total crossouts. The experiment was then repeated for the other font. Scoring was again based on speed and error rate. A similar "recognition" experiment involving six subjects added a booklet that had numbers in the two fonts mixed together on the same page.

Result: A difference of means was statistically significant in favor of BANKERS GOTHIC. However, the differences were very small and decreased with training. In the "transcription" experiment, which extended over the longest testing period, the differences were reduced to practically zero toward the end of the experiment.

* * *

3458 ArmyWES-1953

Army Engineer Waterways Experiment Station,
Vicksburg, Miss.
NOTES ON THE REPRODUCTION OF DRAWINGS IN WATERWAYS EXPERIMENT STATION TECHNICAL REPORTS
Misc. paper no. 5-49, Nov 53, (r. Sep 55), lv.
AD-106 366

Extract: "(T)he Waterways Experiment Station continually strives to improve the appearance and usefulness of its reports, and at the same time to hold their costs to the minimum commensurate with the quality desired. . . The basic principle developed is that practically every drawing can be prepared in such a way as to enable it to be reduced to . . . 8 . . . by 10-1/2 (inches) in size . . . . The border dimensions . . . are 6 . . . by 9 (inches). . . (D)rawings should be prepared with this reduction in mind in order to achieve uniform lettering on all drawings in any one report, and to ensure legibility. . . To illustrate . . ., several groups of sample sheets have been prepared. Group 1 is a folio of sheets illustrating WRICO (similar to LEROY) lettering. The first six sheets contain examples of various styles and sizes of WRICO lettering, including STANDARD

VERTICAL GOTHIC, STANDARD SLANT GOTHIC, EXTENDED lettering, CONDENSED lettering, etc.; each size lettering guide is illustrated with several sizes of lettering pens . . . . The remaining sheets in this group illustrate the reduction . . . (p. 1) to 75 . . . , 50 . . . , 33-1/3 . . . , and 25 per cent of the original dimensions. . . Sheets . . . A are prints of tracings that were prepared . . . for eventual reduction to 6 by 9 (inches); . . . included here . . . to illustrate the form and size of the original tracings. Sheets . . . B are 6- by 9-(inch) reductions of the comparably numbered originals. The reductions range from 33-1/3 . . . to 78 per cent . . . (E)ach of the . . . reductions is clearly legible, even in the case of . . . complicated drawing . . . . This is true because every feature of the original drawings was drawn with the final reduction in mind, and every size of lettering . . . was selected so as to produce the desired size on the . . . final copy. . . For convenient reference, the size of WRICO lettering used has been indicated on all the originals . . . . The process illustrated . . . not only has resulted in drawings of convenient size rather than the bulky, unmanageable plates often found in engineering reports, but also has saved many thousands of dollars . . . . This saving results largely from . . . utilization of the lithographic-offset . . . reproduction . . . in contrast to contact methods (ozalid, black-and-white prints, etc.) required in the reproduction of large-size illustrations. The contact methods are inherently more expensive and also afford no reduction in unit cost as the number of prints increases. Moreover, the page size illustrations eliminate the necessity for costly and time-consuming folding of plates, which often must be done by hand." (p. 2)

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2138 Atkinson-1952

Atkinson, William H., Crumley, Lloyd M., and Willis, Marion P.
Aeronautical Medical Equipment Lab., Naval Air Material Center, Philadelphia, Pa.
A STUDY OF THE REQUIREMENTS FOR LETTERS, NUMBERS, AND MARKINGS TO BE USED ON TRANS-ILLUMINATED AIRCRAFT CONTROL PANELS. Part 5 - THE COMPARATIVE LEGIBILITY OF THREE FONTS FOR NUMERALS
Rept. no. TED NAM EL-609, 13 Jun 52, 27 p., 8 refs.
ATI-157 808

Problem: "(E)valuate the legibility of the forms for numerals developed in this laboratory. . . compared to the forms embodied in Air Force-Navy Drawing 10400 and the font developed by BERGER." (p. 2)

Procedure: "The tests were conducted under conditions of red transillumination ranging from .10 to 3.30 footlamberts and under conditions of daylight illumination with intensities of 11, 24 and 34 footcandles. For the transillumination tests the duration of the exposures

was approximately 200 milliseconds, while in the daylight tests the duration of exposures was 5 milliseconds. The transillumination tests employed 30 subjects while the daylight tests required 48 subjects." (p. 2) Digits were light on dark.

Result: "Where total errors (were) employed as the criterion, it (was) found that under the conditions of the experiment the AMEL proposed form (was) superior to the other two forms with red transillumination or daylight illumination. In the analyses of the error scores for individual digits, the digits of the AMEL proposed series (were) not always significantly more legible than their counterparts in the (BERGER and AND 10400). However, it was found that where significant differences in error scores (were) obtained, it (was) always the AMEL proposed digit which produce(d) the fewer errors when compared with a digit of one of the other two forms. . . The (specific) results of these comparisons (were) as follows:

1. "With transillumination,
    a. "the AMEL proposed 1, 3, 4, and 5 (were) significantly more legible than their counterparts in the AND 10400 series. . .(,)
    b. "the AMEL proposed 2, 5, and 9 (were) significantly more legible than the corresponding digits in the BERGER font. . .(, and)
    c. "the BERGER '1' and '3' (were) significantly more legible than the same digits in the AND 10400 series while the greater legibility of the BERGER '4' approache(d) statistical significance.
2. "With daylight illumination,
    a. "the AMEL proposed '4' and '5' (were) significantly more legible than their counterparts in the AND 10400 font, while the AMEL proposed '3' and '6' approach(ed) statistically significant better legibility. . .(,)
    b. "the AMEL proposed '2' and '5' (were) significantly more legible than the corresponding digits in the BERGER font. . .(, and)
    c. "the AND 10400 '2' (was) significantly more legible than the BERGER '2' while the BERGER font ha(d) the more legible digit when the '4' (was) considered." (p. 25)

The authors recommend "the digits of the AMEL . . . form . . . for use in aircraft on plastic console panels." (p. 2)

* * *

2608 Baker-1954

Baker, Charles A. and Grether, Walter A.
Aero Medical Lab., Wright-Patterson Air Force Base, Ohio
VISUAL PRESENTATION OF INFORMATION
WADC Technical rept. 54-160, Aug 54, 111 p., refs.
Project 7180
AD-43 064

Abstract: "An important factor in the design of equipment for maximum efficiency of human operation is the design, illumination, and arrangement of visual displays which provide information to the human operator. This report provides a compilation of general human engineering recommentations and presents some of the supporting presentations of information. . . Liberal use is made of pictorial, graphic, and tabular presentations to illustrate the data and design recommendations. . ." (p. iii)

Contents (with underline emphasis on those parts pertinent to this handbook):

I. Mechanical indicators.

- A. General considerations include methods of use (i.e. quantitative, qualitative, and check reading; setting; and tracking), conditions of use (i.e. reading distance, angle of view, illumination, presence of other instruments, and location and method of actuation of related controls), and check list for a good indicator.
- B. Selection of mechanical symbolic indicators includes distinction between symbolic and pictorial indicators in displays, basic symbolic indicator types (i.e. counters, scales, pointers, and their selection), table of recommended indicators according to use, variations in basic indicator types (i.e. circular and curved scales, and horizontal and vertical straight scales), and long scale indicators (i.e. counters, subdials, multiple pointers, and various pointer-scale combinations).
- C. Selection of mechanical pictorial indicators includes pictorial representation of aircraft attitude, direction, and position in space; and distinction between flight (tracking) and navigation (orientation) displays.
- D. General design recommendations include those for moving pointer/fixed scale, moving scale/fixed pointer, and counter type indicators.
- E. Scale design includes definition of terms (for scale range, and numbered and graduation interval values), scale numbering and graduation interval, table of recommended scale designs, exceptions, transformed scale values, scale dimensions - low brightness requirements (i.e. graduation mark dimensions and spacing), graduation mark dimensions when low brightness not required, scale interpolation, and additional recommendations.
- F. Instrument zone markings include color and shape coding methods.
- G. Pointer design.
- H. Instrument identification includes labeling; color, shape, and position coding;

and instrument configuration.

I. Numeral and letter styles.

II. Warning devices include warning light location, brightness, identification, and intermittency characteristics; and caution and on-off indicators.

III. Cathode-ray tubes and signal coding.

A. Introduction includes definitions of terms (for target, signal, trace, noise, clutter, background, surround, brightness contrast, and scan line), common types of radar presentation (i.e. A-, B-, C-, F-, PPI-, and Sector-scan), and a check list for good design practices in cathode-ray tubes.

B. Cathode-ray tube resolution, including eye versus radar resolution.

C. Cathode-ray tube visibility, including visual factors, signal size and brightness relationships, design factors that affect visibility (i.e. signal size, scope brightness and its adjustment, contrast direction, and scope brightness distribution), adaptation level, general recommendations, signal strength, duration of pre-exposure brightness, signal duration, viewing angle, viewing distance, and screen size (for both visibility and resolution considerations).

D. Workplace lighting and cathode-ray tube displays include general recommendations, selective spectrum and polaroid lighting, and summary table of lighting systems.

E. Methods for indicating range on radar displays include range markers and mark interval, range ring separation distance, electronic range cursors, pantographic methods, evaluation of range aid methods for both speed and accuracy, and general conclusions.

F. Methods of indicating bearing on radar displays include dial, cursor, counter, pantograph, and overlay methods; evaluation of bearing aids for accuracy and speed; time delay in data transmission; and system consideration in radar design.

G. Three-coordinate information displays, including general discussion and the coding of the third coordinate.

H. Visual coding - the display of additional target data includes what may be coded, various coding methods, subjective scaling, code compatibility, and the following coding methods: color, shape, area, visual number, line length, angular orientation, brightness, stereo-depth, and compound coding, followed by recommendations for compound coding and a summary and table of coding methods.

IV. Printed materials.

A. Legibility of printed matter includes books, pamphlets, and detailed instruction cards (for their style of type, type form and size, line length, leading, paper, contrast, space between columns, margins, and illumination); and decals, check lists, and labels (for their style and size of print, contrast, word selection, and brevity).

B. Design of graphs, tables, and scales for numerical data.

V. Instrument panel layout, including check list for good layout, representation of

planes in space, locational parameters (viz. optimum position, viewing angle and distance, horizontal and vertical separation, position of adjusting knobs and switches, and right-/left-handed operation), instrument arrangement and pointer alignment, and combinations of instruments.

VI. Lighting.

A. Definition of terms, including photometry, illumination/illuminance (candle, footcandle, and lumen), brightness/luminance (candles per unit, footlambert, and lambert), luminous reflectance (diffuse, specular, compound, reflectance and transmittance factors, and selective reflectance and transmittance), brightness contrast, visual angle and acuity, conversion factors for brightness units, and a table of approximate brightnesses.

B. General workplace lighting, including illumination levels, general methods of light distribution (direct, indirect, and diffuse luminaires), glare (direct and specular) and its reduction, surround brightnesses, types of illuminants, surface reflectance and color, specific color coding recommendations (by function of display), and color selection.

C. Instrument and control console lighting, including dark adaptation, reflections, brightness requirements, uniformity of distribution, special conditions (lightning flashes, searchlights, rocket and gun flashes, daytime flight, high altitude daytime flight, and chart reading), selection among instrument and console lighting systems (advantages and disadvantages of flood, indirect, edge, and rear lighting), and general recommendations.

VII. Visual detection and identification, including visual acuity (resolution, detection, stereoscopics, glare, perceptibility, visibility, retinal location, and as a function of illuminant color), detection and recognition of colored targets (surface color, lights, and recognition thresholds, target detection against non-uniform backgrounds, pattern recognition and identification, magnification aids, and visual estimations of target parameters (size, range, velocity, acceleration, etc.).

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3369 Bauch-1954

Bauch, William F., Jr. and Nagel, John T.
Illinois Division of Highways
EXPRESSWAY SIGNS IN THE CHICAGO METROPOLITAN AREA
Highway Research Abstracts, 24:5 (May 1954) 33-39, 4 refs.
Paper presented at the Thirty-Third Annual Meeting of the Highway Research Board, January 12-15, 1954

Abstract: Methods and activities used to establish standards and policies, and to coordinate and unify design details, for signs on the expressway system in the Chicago Metropolitan Area, have been discussed. Observation tests were conducted from moving vehicles using variable numbers of observers (who were men from various highway

agencies). Conclusions were drawn on the basis of questionnaires completed by the observers. The final sign choices included: (1) dark background with white letters, (2) moulded plastic button reflectors, and (3) 6-, 8-, and 12-inch letters on various signs. Also, "the message on the sign determined its overall dimensions." (p. 36)

* * *

2613 Bauer-1962

Bauer, Herbert J.
General Motors Research Labs., Warren, Mich.
SOME SOLUTIONS OF VISIBILITY AND LEGIBILITY PROBLEMS
IN CHANGEABLE SPEED COMMAND SIGNS
In DRIVER CHARACTERISTICS, Highway Research Board
Bulletin 330, (Washington, D. C., National Academy
of Sciences-National Research Council Publication
1010, 1962), p. 60-68.

Problem: "This report details the . . . design criteria specified for (and experimental development of) a discrete-bulb, matrix, speed command sign." (p. 60)

Procedure: Criteria established for the sign were as follows:

1. psychophysical - instantly changeable numerals, minimum of reading errors, legible from 500 feet, exposure time approximately 1 second (for test purposes), useful for day and night viewing without electrical or mechanical changes, tolerance of 1/16-inch of solid frost or ice on the sign face, some bulb failure permissible, chromatic quality of numerals somewhere between yellow and amber, numeral strokes to be linear rather than discrete points of light in appearance, and sign to be capable of being blanked without the appearance of spurious numerals.
2. mechanical - two by four feet in overall size, thickness to about 12 inches, weight less than 100 pounds, minimum dirt collection permissible, adequate ventilation, ease of maintenance even under adverse conditions, and no day-night mechanical changes.
3. cost - minimum, using standard available parts wherever possible.

"Before experimentation a number of commercially available (highway and sports arena type) signs were tested. . . Those tested failed on two primary grounds: legibility at the specified distance and lighting condition, and/or too many reading errors when viewed at the criterion distance and exposure time." (p. 62) A new numeral set was developed for and tested in the 5 by 7 matrix. "The prototype configurations were tested under three different conditions:

1. "Bright sunlight, clear sky, with sun incident on the sign face with minimum shadow in the bulb cells.
2. "Bright sunlight, clear sky, with sun behind the sign (the sign oriented for maximum brightness behind it).

3. "On a dark, moonless night.

"One digit was presented at a time to each of (twenty) experimental subjects. . . Exposure time was 1 (second). . . at a distance of 500 (feet) . . . (R)andom bulb failures were introduced . . . ." (p. 62-63) Stroke linearity was achieved by locating the colored frosted bulbs in a honeycomb-like structure of rectangular cells. "The linearity can be further enhanced by the use of lightly frosted glass or plexiglass in front of the cells. However, such an addition is in conflict with some of the other requirements (especially daylight usage) of the sign." (p. 63)

Result: After many trials and errors delineated in the article, the following sign specifications were developed:

1. "The sign consists of a 5 by 7 bulb matrix composed of rectangular cells 2-3/8 by 2-3/8 (inches) square inside dimensions by 4-5/8 (inches) in depth. The cell matrix interiors are painted reflective white with the exception of those cells which do not have bulb sockets, these have a yellow background (sides and edges white) of the same shade of yellow as the bulbs in unilluminated mode. The bulb sockets (ceramic) are on 2-1/2-(inch) centers.
2. "The numeral configurations shown . . . have been found most suitable.
3. "The recommended bulb is GE 25AY, the yellow enameled 25-watt bulb rated at 130 volts.
4. "Bulb-operating voltage is 110 volts . . . The rated life . . . is 1,000 (hours). At . . . operating voltage the life is increased to 9,340 (hours which is) well within the 3,000-(hour) replacement schedule . . . .
5. "The face of the sign is equipped with KoolShade screen, type RB. . . mounted so that it is immediately adjacent to the front edge of the matrix cell. . . (T)he angle of the louvers (must be) slanted downward. The screen as well as the rest of the sign is painted flat black." (p. 67)

The specifications listed met the following requirements:

1. "Legible at 500 (feet) with 1-(second) exposure time when viewed under the following conditions:
   (a) Bright sunlight, clear sky with sun incident on sign face with minimum of shadow on the bulb cells.
   (b) Bright sunlight, clear sky with sun behind the sign. The sign-oriented maximum brightness behind it.
   (c) Dark rainy, moonless night.
   (d) When sign face is covered with 1/17 (inch) of ice.
   (e) When as many as five bulbs have failed.
2. "Numerals have definite chromatic (yellow) hue in both daylight and night conditions.
3. "Nighttime legibility is as adequate as daytime legibility without the necessity of components designed to reduce bulb voltages with lower ambient lighting.
4. "Blanking of sign face when power is removed . . . so that . . . no spurious numeral is visible under either day or night viewing." (p. 68)

* * *

2141 Bendix-1959

Bendix Radio Div., Bendix Aviation Corp., Baltimore, Md.

DESIGN FOR LEGIBILITY OF VISUAL DISPLAYS

Preliminary study rept.

Rept. no. 481-1016-97A, 15 Feb 59, 52 p.

AD-230 962

Purpose: "The main purpose of this report is to call attention to the need for more legibility in the various characters used for visual displays of information. All too often, displays best signal a need for their own improvement. A little new information, plus a careful examination of present data, could readily effect this change: an improvement which would reduce error and aid reading. Not only is the need for greater legibility already serious, but the need is bound to grow as systems become more complex and time allowances shorter." (p. 1) Studies to date "center around three main topics:

1. "Visibility - Studies made to determine those characteristics which provide visibility at greatest distance or visibility of smallest size of characters. In addition, studies were made to determine optimal size of characters for various viewing distances.
2. "Legibility - Studies concerned with those characteristics of type which assure positive identification of individual letters and numerals. Absolute legibility is essential in today's application of displays.
3. "Readability - Studies directed toward ease and rapidity of reading and concerned with rapid recognition of words, word groups, abbreviations, and whole numbers." (p. 7)

Procedure: In studying previous work, and in the "design and test(ing) for optimized legibility. . . (t)his report is directed toward -

1. "Arranging the presently available data in a form directly usable by specification writers, design engineers, and others for maximum utilization in assuring optimized display design.
2. "Clarifying the language of communication of visual display requirements between specification writers, design engineers, and suppliers.
3. "Analyzing the existing, extensive study data and, on the basis of such analysis, recommending the alphabetic and numeric designs best suited to the provision of higher error-free legibility.
4. "Determining what further experimentation is most likely to result in further improvement in character design." (p. 5)

Result: The following outline of contents, including excerpts from the information contained therein, shows the results of this very comprehensive study of the literature and the state-of-the-art conclusions derived by the authors from the literature studied:

I. Purpose of this report.

A. The need for higher legibility of visual displays. "All too often, displays best signal a need for their own improvement. . . Not only is the need for greater legibility already serious, but . . . is bound to grow as systems become more complex and time allowances shorter." (p. 1)

B. Bendix's interest in the problem. "(I)n the design and manufacture of . . . equipment requiring alphabetic-numeric displays and clear identification and marking of controls, . . . (determine) those styles . . . which can be expected to produce optimum ease and rapidity of reading and maximum error-free legibility." (p. 1)

C. Bendix's experience and understanding of the problem. "(W)hich combination is the best for each of . . . various display requirements encountered(?). . (A)pplicable data are . . . scattered . . . (I)ndividual excellence of . . . displays and markings does not automatically insure an optimized total system. . . To date, it has been almost impossible to design completely optimized and . . . compatible alphabetical and numerical displays within a complex system. This is primarily because the necessary design data are so scattered, ambiguous, and confusing. . ." (p. 2-3) The Bendix approach is as follows: "(f)irst, the . . . use(r) task is analyzed; second, the environment is examined; third, . . . the lettering style, size, proportion, and contrast are specified. . . (p. 3) (T)he importance of good legibility is obvious beyond any need for elaboration." (p. 2)

D. Indicated course of action. (See items 1.-4., in the above Procedure.)

II. Statement of the problem.

A. Availability of data. "In dealing with (the three items stated in Purpose, above), the studies deal with the many factors which influence (them). Size, stroke width, and width-to-height ratios are important. So is the spacing between characters, words, and lines. But in addition, the effects of lettering style, geometrical form, the use of capitals versus lower case, color, viewing distance, vibration, human stress, and the user's visual acuity must be taken into account. Also critical is the whole complex related to contrast: contrast with background, black-on-white versus white-on-black, illumination, and intervening mist or smoke." (p. 7)

B. Value of data. "The factors investigated by experimental psychologists are those which are encountered in the equipment design field, and the results obtained sum up to valid findings applicable to real display problems. A thorough organization of the valid data is very much needed and would be immediately useful." (p. 9)

C. Limitations. Included here is "a family tree of typical (Government) specifications and the exact words governing lettering. . . (I)nsofar as they go, . . . specifications are so worded as to keep the door wide open to excellence of design. At the same time, . . . writers of specifications do not have enough precise data to close the door on poor design . . . (M)any specifications go no

further than to require GOTHIC type or 'similar simple style.'. . (T)he first limit on the improvement of legibility is . . . the scattering and the ambiguity of the information about existing, available type faces. . . Second, there is an acute scarcity of good type styles to meet the requirements of unusual applications. . . The reason . . . is that for centuries type designers have paid prime attention to beauty of the printed page. . . (,) achiev(ing) great heights in beauty of type design, often at the direct expense of the quality of legibility desired for expressing vital quantities or commands . . . (p. 9) In spite of the fact that in the history of printing over ten thousand type styles have been designed, and hundreds of GOTHIC styles have been designed just since 1920, completely satisfactory displays are not yet achievable for some applications. . . The FUTURA family . . . is the most useful, but is not completely optimal for many applications." (p. 13)

D. Positive steps already taken. "An excellent example . . . is to be found in the preparation of . . . AND 10400, superseded by MIL Standard MS33558 (ASG) . . . (T)he NAMEL style . . . also presents a design for higher legibility. . . Quite important among the positive steps . . . is the restraint which has been exercised by not calling out in specifications specific styles . . . ." (p. 13)

E. Definitions. "The following terms are the worst offenders (p. 13) . . .: Visibility - the quality of an item which makes it separately visible from its surroundings. . . If . . . three width . . . and five height elements can be distinguished, we may say that the elements of the letter are visible. . . (T)he popular nominal width-to-height ratio of type is given as 3 (to) 5. Normal human vision under average lighting can see an object subtending a visual angle of one minute. It follows then that a letter to be visible . . . must be five minutes of visual angle in height. . . about one sixty-fourth of an inch at normal reading distance . . . This is a threshold value, not a recommendation. . . Legibility - the quality of a letter or numeral which enables the observer to positively and quickly identify it to the exclusion of all other(s) . . . (D)ifferent type styles possess different degrees of absolute legibility. Every factor mentioned in (II. A., above) is involved in the problem of absolute legibility. . . (p. 15) (T)he quality of legibility is mainly determined by the dimensions and style of the character . . . (p. 22) Readability - the quality of a group of letters or numerals of being recognizable as words or whole numbers. Although similar in many respects, it is quite a different thing from legibility. . . Involved . . . are . . . spacing of the individual characters, . . . words, (p. 15) . . . (and) lines, and the ratio of character area to background area. . . (T)he quality of readability is mainly determined by the dimensions of surroundings of the individual characters in relation to other characters . . . GOTHIC Type - . . . 'any character which is of uniform stroke width and whose strokes terminate without decorations or embellishments called "serifs".' In printer's parlance, it also includes styles which have very minor serifs designed to provide very sharp terminations. . . a reference to

COPPERPLATE GOTHIC . . . (H)owever, . . . (i)n the traditional definition, . . . GOTHIC means just about everything that the . . . definition (above) does not. . . (p. 22) Printer's Terms of Measurement - . . . The printer's 'point' is one seventy-second of an inch. . . (w)hen used as a unit of measure . . ., but . . . as a measure of type size, it means the size of the slug upon which the character is cast. . . A close approximation of character height expressed in points can be made by considering the point as being one one-hundredth . . . of an inch." (p. 23)

F. Preferred GOTHIC styles. The following list was a tentative selection by Bendix: Very Light Styles - FUTURA LIGHT, FUTURIA LIGHT, HEADLINER NO. 48, LINING METROTHIN, METROLITE, SANS SERIF LIGHT, TEMPO LIGHT, and VOGUE LIGHT. Light Styles - FUTURA BOOK, SPARTAN BOOK, SANS SERIF MEDIUM, SANS SERIF MEDIUM CONDENSED, and TEMPO MEDIUM. Medium Styles - FUTURA MEDIUM, AIRPORT GOTHIC, HEADLINER NO. 50, SPARTAN MEDIUM, FUTURA MEDIUM CONDENSED, AIRPORT MEDIUM CONDENSED, SPARTAN MEDIUM CONDENSED, SANS SERIF BOLD, TEMPO BOLD, VARITYPE NO. 660, TEMPO BOLD CONDENSED, and VOGUE BOLD. Medium Bold Styles - ARTYPE S-274 (NAMEL), FUTURA DEMIBOLD, AIRPORT SEMI BOLD, ARTYPE NO. 1200, FUTURIA DEMIBOLD, HEADLINER NO. 52, PHOTOTYPE 1900 SERIES, SPARTAN BOLD, VOGUE MEDIUM, 20th CENTURY BOLD, and MIL Standard MS-33558. Bold Styles - FUTURA BOLD, AIRPORT BOLD, HEADLINER NO. 54, FUTURA BOLD CONDENSED, AIRPORT BOLD CONDENSED, HEADLINER NO. 60, METROBLACK, VARITYPE NO. 670, SANS SERIF EXTRA BOLD, TEMPO HEAVY, FUTURIA BOLD, and VOGUE EXTRA BOLD. Engraving Styles - GORTON EXTENDED, GORTON MODERNE, GORTON NORMAL, and GORTON CONDENSED.

G. Inadequacy of existing styles. "Some of the styles shown (above) qualify as 'preferred' only because they are the best available." (p. 27) In a simulated comparison, it was "clearly seen that FUTURA is more legible than COPPERPLATE of an equal area. . . Experimental . . . studies have indicated that legibility can be increased by using wide characters. Optimum for absolute legibility (not . . . readability) appears to occur at a width of 1.3 times the height. . . It is clear (however) that design, not width, is the more important determiner . . . (T)here are occasions when wide characters should be used. . . (for) example . . . a digital indicator using a wheel or tape to carry the characters to a position in a window. . . Specification MIL-P-7788 suggests extended styles for letters, but wisely suggests nonextended . . . for numerals, even though extended (wide) numerals could be superior." (p. 27)

III. Experimental psychology findings.

A. Common sense. "(W)hen experimental data . . . have accumulated, the primitive use of common sense should be shelved . . . . The accumulated data upon the subjects of visibility, legibility, and readability have reached the point

which indicates that common sense on the subject is no longer valuable in design." (p. 29)

B. Stroke width. "Berger found . . . a 1 (to) 8 ratio of stroke-to-height . . . best for black letters on a white background. . . Further, (he) found that when the characters were white on . . . black . . . , the greatest distance for reading was achieved with a stroke width of . . . approximately 1 (to) 13. . . Berger's experiments dealt with optimal conditions of lighting. . . (p. 29) Berger . . . (also) explor(ed) night reading . . . (,) us(ing) white letters on black. . . (with) floodlighting. The optimum stroke turned out to be . . . the same as for daylight. (Using) luminous characters . . . the results (gave an) amazing. . . ratio of 1 (to) 40. . . (I)n the early uses of neon tubing to form sign displays, . . . a ratio of 1 (to) 100 and better. . . was customary . . . Modern neon sign us(ing) multiple rows of tubing . . . are more attractive . . . but far less legible . . . This phenomenon of white letters on black requiring a narrower stroke width than black . . . on white is a familiar one . . . (F)actor(s) . . . such as bad eyesight; air, dust, smoke, or mist intervening between the display and the observer; vibration; nervous stress; etc., cause the light areas to appear larger than they are. . . Darkness cannot spread into light areas but light can be dispersed into dark areas. . . This effect is more pronounced as the intensity of the light is increased. . . Just as it can be shown that very thin strokes are required for very highly luminous characters, it can also be demonstrated that very thick strokes are required for black letters on a very highly luminous background. . . (p. 31) A typical case . . . is a warning light having its label engraved directly on the lens. Here, thick strokes are desirable, but there is a practical limit." (p. 33)

C. Low levels of illumination and contrast. "(A)s . . . illumination (or contrast) is reduced, the thick letters become relatively more readable than the thin ones. This is true for both black-on-white or white-on-black. . . (A)s . . . illumination . . . and the consequent contrast is reduced, a new rule comes into effect. There seems to be a common meeting point at very low levels of illumination and contrast of an optimum stroke width for both white-on-black and black-on-white . . . . The complete answer has not yet been found . . . . There are good reasons to expect that . . . the most important factor controlling legibility is area . . . (---)a simple question of visibility . . . ?" (p. 33)

D. Legibility at great distance or with small size characters. "There are good reasons to expect . . . that . . . the most important factor governing legibility of distant or very small type is geometric form. . . If the individual characters can be made sufficiently distinctive in geometric form, the downward range of legible size can be extended." (p. 35)

E. Width-to-height ratio. "The experimentally derived optimum . . . for certain characters appears to be of the order of 1.3 (width to) 1.0 (height) . . . partly because many displays must be viewed from an unfavorable angle, which

artificially reduces the apparent width, and is also partly due to the fact that there is opportunity to emphasize the distinctive features of some characters by extension of the geometric patterns in width. . . In matters of proportion, the modern designer bows in admiration . . . (to t)he classic ROMAN alphabet . . . . In general, the vertical strokes were made thick in order that they would remain visible at wide viewing angles. . . (p. 35) (W)hen successive vertical strokes occur, the most significant were selected for thickening. . . (W)ithout exception, the most poorly legible styles are all the result of an attempt to 'horse' the design into a standard (or fixed) ratio and that all the most legible type styles are the result of pursuing good geometric expression . . . ." (p. 37)

F. Comments on some proposed styles. "The NAMEL . . . was based partly upon . . . MACKWORTH . . . Another experiment us(ing) numerals of very radical design. . . reduced (errors) to near zero. . . (p. 37) Perhaps such unmistakable characters represent a step in the right direction." (p. 39)

G. Experimental methods. "(M)any different criteria and methods (have been) used. Careful study is needed . . . (I)t is difficult to test legibility. . . (W)e . . . want to know . . . how good is the design for optimal or near optimal operating conditions? However, we cannot get valid test results by testing under optimal conditions. . . (L)egibility cannot be maximized using only one style of lettering, however good, for all applications." (p. 39)

H. Accountant's numerals. "Absolute legibility . . . has always been of prime importance . . . With the advent of typewriters and business machines, this science of handwriting has largely been abandoned, but the records (should) be studied." (p. 41)

I. Legibility and beauty are not synonomous. "However, let us not jump to the conclusion that legibility and beauty are irreconcilable. They are . . . in fact, not separable." (p. 41)

IV. Summary.

A. Specifications could be more informative. "This is not because of errors to be found in the specifications, but rather that some erroneous inferences could easily be made from what is said. . . (T)he fault lies not with the writers but with the confusing data with which they have had to work. This report makes an effort to clarify that situation. . . (p. 43) In spite of the work that has been done, there is still room for improvement in type design. The word GOTHIC should never be used in specifications . . . . (p. 44) Use of the term point should be avoided . . . . There is nothing to be gained by specifying width-to-height ratios . . . (M)ost important of all, stroke width should be determined on the basis of contrast or of one of the factors interrelated to it: illumination, size, or time of exposure, in this manner:" (p. 45)

| condition | variety of style | stroke width |
|---|---|---|
| low level of illumination: | BOLD | 1:5 |
| low contrast with background: | BOLD | 1:5 |
| contrast value of 1:12 and up- black on white: | MED. BOLD - MED. | 1:6 to 1:8 |
| white on black: | MEDIUM - LIGHT | 1:8 to 1:10 |
| dark letters on illuminated background: | BOLD | 1:5 |
| illuminated letters on dark background: | MEDIUM - LIGHT | 1:8 to 1:10 |
| highly luminous letters: | VERY LIGHT | 1:12 to 1:20 |
| characters to be read at great distances or of below optimum size: | BOLD - MED. BOLD | 1:5 to 1:6 |

(above from p. 45)

B. A job needs doing. "We hesitate . . . to estimate what the lack of precise information has cost our country in dollars, delays, and in human life." (p. 45)

V. Program for continued study.

A. Approach. "(M)any details of useful information could be added." (p. 47)

B. Objectives. "Suggested preliminary objectives are: a. . . (S)earch . . . Government specifications, and abstract all (pertinent) data . . . . b. Refine and expand . . . material . . . in (II. E., above; definitions) . . . . c. Prepare a complete exposition of available, legitimate alphabets . . . d. Prepare clear explanations of why certain . . . styles should not be used, on the basis of valid experimental data. e. Expand the list of available styles . . . (and d)efine, among these, (those) which meet each particular class of operating requirements . . . (p. 47) The list of equivalents should be . . . expanded and . . . checked for accuracy. . . f. Prepare (an) . . . explanation of the various processes by which lettering for displays is produced and used . . . ." (p. 49)

VI. Communication between psychology and design. "One of the shortcomings of many design programs is a lack of real understanding between psychologists and design engineers. . . The psychologist sometimes overestimates the value of his work in human factor studies, and the design engineer often underestimates it. Often the psychologist is content to dig out useful facts without taking on the task of transforming them into tools useful in solving engineering problems, or if he does try to do this, he may not be properly understood. . . On the one hand, we have capable experimenters in human factors discovering facts of extreme usefulness to equipment design, and on the other . . . , we have busy design engineers who, with considerable justification, say, 'Put your facts in usable form, or go away.'" (p. 51)

* * *

3330 Berger-1944b

Berger, Curt

STROKE WIDTH, FORM AND HORIZONTAL SPACING OF NUMERALS AS DETERMINANTS OF THE THRESHOLD OF RECOGNITION (PART II)

Journal of Applied Psychology, 28:4 (August 1944)
336-346
Also in READINGS IN EXPERIMENTAL INDUSTRIAL PSYCHOLOGY, Milton L. Blum, Editor, (New York, Prentice-Hall, 1952), p. 295-303, 7 refs.

Problem: "(I)nvestigate (using white and luminous numerals on black backgrounds, and black numerals on a white background, under conditions of night-vision, and with medium dark-adaptation) the influence of stroke-width . . . , specific form-factors, distances between the strokes of numerals, distances between two numerals(,) and surroundings(,) upon the threshold of recognition, with a view toward improvement of the recognizability of . . . (p. 303) luminous numerals during night-conditions." (p. 295)

Procedure: As a preliminary procedure, "the optimal light-intensities for white numbers of optimal day vision under night-conditions were determined, using 5, 10 and 15 watt lamps as light-sources for reflecting light. . . , (p. 295) in the center, some inches below and before the . . . license-plate. Ten to 15 Watt-lamps were found practically equal and better than 5 Watt. A further increase . . . (p. 298) did not seem to improve recognizability . . . . Similar experiments were made with luminous numbers of equal appearance, cut out of card-board and illuminated from behind, the light-source being in a light-tight box. Ten Watt lamps were found most satisfactory." (p. 298) The author acknowledges that the major "experiments . . . should have been made in combination with (the) preliminary . . ." (p. 298) procedures. "Such a thorough investigation would . . . have been carried out but for two reasons. . . First, if reflected light is used under night-conditions, the numerals were bound to have . . . the optimal daylight structure (6-millimeter width), since it is . . . practically impossible to use on the same plate two differently constructed numbers for day- . . . and night-vision, both with reflected light. . . Second, the intensities . . . should be kept low because . . . the lamps are run from motorcar batteries. Furthermore, . . . (t)he lower the intensities, the less aberration and the fewer glaring effects at night. . . Subsequently, experiments were made with the number(s) 8 and . . . 2, using widths of strokes between 2 and 10 (millimeters) for numerals with reflected light, and . . . 1 (to) 5 (millimeters) for luminous numerals." (p. 298) Also "compared . . . (were) luminous five-number groups with only 2 (millimeter) stroke-width, the old DANISH numerals with reflected light(,) and optimally legible white numerals of 6 (millimeter) stroke-width and with reflected light." (p. 298) Five subjects were used in the first experiment and four in the second.

Result: The following results were obtained from the experimentation:

1. Optimal average recognizability, for numerals in an area 42 by 80 millimeters each, showed stroke-widths of 6 and 10 millimeters and stroke-width to inner horizontal distance ratios of about 1:5 and 1:2.2, for white-on-black and black-on-white (figure-to-ground) numerals, respectively. "The white numerals are (,) under these conditions, singly, about 8.2 per cent more recognizable than the optimally constructed black numerals for the same area. . .
2. "Investigating many detailed characteristics of form, it was found that the angle under which two horizontal (or two vertical) lines are connected has a particular importance for the recognition of a numeral. The recognizability is best with angles which cut the adjacent parts of the area into two equal halves. A vertical or horizontal connection is least recognizable. . .
3. "A 5-number group requires about 10 per cent more space between the numerals than 2 numbers alone, even though the space between the 2 numerals already has been adjusted to standard. . .
4. "A white frame around white numerals improves their legibility only if at a certain distance from the top and base of the numerals, and only if its width is equal to the stroke-width of the numerals. Then the improvement is about 9 per cent. . .
5. "Under ordinary night-conditions (medium dark adaptation) very slender, luminous numerals at threshold brightness are about 17.8 per cent more recognizable than optimally constructed white numerals with reflected light." (p. 303)

As a result, "(a) construction is found for 9 numerals, white on black background, luminous during night-conditions, which are optimally recognizable [standard area-42 (millimeters) X 80 (millimeters)] and which at the same time are adjusted to standard in such a way, that each single numeral as well as 2- and 5-number constellations appear or disappear at the same distance from the eye, a distance which is the greatest possible distance for the particular area chosen." (p. 303) Finally, "(t)he relations of these results to previous theoretical work are discussed . . . ." (p. 303)

* * *

3361 Berger-1948

Berger, Curt

Copenhagen U. (Denmark)

SOME EXPERIMENTS ON THE WIDTH OF SYMBOLS AS DETERMINANT OF LEGIBILITY

Acta Ophthalmologica, 26:4 (1948) 517-550, 25 refs.

Problem: "This paper describes and analyzes some experiments about the influence of width of area upon the legibility of some numerals. . . In this paper we will try to consider legibility as a purely physiological function of the human retina . . . (p. 518) Considering the complexity of legibility . . . , no one single method can possibly claim to

be 'the one' method of measuring legibility. . . Speed of reading . . ., eye-movements, blinking rate, muscular tension, heart-rate, etc. . . are all interesting details . . ., but there is no doubt that the structure and the function of the retina and the total visual reception organ is the physiological basis of reading as of all other visual functions. . . The functions of the human eye can be divided into: (a) Light sense, (b) Color sense, (and) (c) the physiological resolving power. . . (I)t must be assumed, that both, light sense and physiological resolving power are always involved in experiments of legibility of printed letters or words, black on a white background." (p. 522-523)

Procedure: "In physiological optics we can . . . determine the importance of a factor for the function of the human eye by threshold determinations. . . The following thresholds can be used: (1a) The 'minimum legible' . . . is found by decreasing the size of letters . . . . (1b) The 'minimum legible' can also be achieved by changing the distance between observer and test-object. . . (2a) (T)he differential threshold. . . could be achieved by gradually changing the reflection coefficient of the letters from the one possessed by the . . . background . . . (2b) (T)he intensity threshold . . . is really the basis of Luckiesh's visibility meter. . . (3) (D)etermine the time-limit at which a letter is legible. . . The experiments were carried out monocularly with (2)-5 subjects. . . (p. 523-524) An apparatus is described with which visual distance thresholds (moving away to, and toward ---the subject---from 50 centimeters with the screen at 22 foot-candles) and intensity thresholds (light variations between 2 and 20 foot-candles) with 10 symbols of different width (1.5, 2.0, 2.75, 3.3, and 4.15 millimeters), five 0('s) and five 5('s) but equal height: 6 (millimeters), have been determined." (p. 548) A third experimental method involved use of the Luckiesh-Moss Visibility Meter. "Experiments were performed with photographic reproductions on one hand and printed reproductions on the other . . . ." (p. 548)

Result: "The experiments . . . show(ed) a general increase of legibility with increased width of numeral. . . In two (light intensity variation and Luckiesh visibility apparatus) of the three methods, the increase of legibility with width is more pronounced in the case of . . . (the 0) than in the case of the . . . (5)." (p. 548) No significant differences were found between the use of photographic vs. printed reproductions. The difficulties and problems associated with use of the Luckiesh-Moss Visibility Meter are discussed. The results of all experimentation here "are explained on the basis of pure physiological factors of the human retina . . . and the relatio(n) . . . to other theories (Spencer and Moon, Kreiker, Luckiesh-Moss, etc. . .) . . . (p. 548) The larger increase of legibility with number 0 can be explained on the ground that increasing the width of the 0 . . . corresponds to the increase of distance between two parallel vertical bars. . . The increase of the total length of the line of which the 0 is composed seem(ed) to have no influence upon (the) dependency . . . . The minor increase of legibility . . . in the case of number 5 can . . . be explained with a similar reason . . . (by t)he fact that the center of the 5 . . . is filled with the line representing this typical form, (thus) bring(ing) . . .

about an increase of width . . . (but) not increas(ing) the white space considerably. . . (and rather increases) the length of the horizontal borders between the black . . . lining . . . (thus) increas(ing) the resolution threshold but much less . . . than in the case of the distance between two parallel lines." (p. 545-546)

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3367 Berger-1950

Berger, Curt

Copenhagen U. (Denmark)

EXPERIMENTS ON THE LEGIBILITY OF SYMBOLS OF DIFFERENT WIDTH AND HEIGHT

Acta Ophthalmologica, 28:4 (1950) 423-434, 5 refs.

Problem: Investigate "the influence upon the threshold of legibility of the height of three black symbols (5, 0, and E, each in three different widths) on a white background . . . ." (p. 433)

Procedure: The following five different heights were used for each of the symbols 5, 0, and E: 2.5, 4.0, 5.5, 7.0, and 8.5 millimeters. For each height, each symbol had a width of 1.0, 2.5, or 4.0 millimeters. Stroke-width was held constant at 0.4 millimeters for all 15 variants of each symbol. "The method used (three subjects, monocularly, and) was described in detail in . . . (Berger-1948)" (p. 423)

Result: "(T)he effect of increasing the height only (was) very similar for all symbols . . . . The threshold of their legibility, defined by the distance of the test-object from the subject, increase(d) slightly less than proportionally as (a) function of height. . . The legibility of the number 0 increase(d) more with increasing width than the . . . 5. This applie(d) to all heights investigated. For heights above (about) 3.0 (millimeters), the 5, when very narrow, (was more) legible tha(n) the 0, a relationship . . . which reverse(d) gradually with increasing width. (When) the height (was) decreased below (about) 3.0 (millimeters), the legibility of the 5, when very narrow, gradually approache(d) . . . the 0 and eventually equal(led) it. . . (R)esults with the letter E resemble(d) those with the . . . 5, except when very narrow. . . The results (as a whole, were) explained as . . . function(s) primarily of spatial relations between activated units of the fovea, and second(arily) of the 'aligning power'." (p. 433-434)

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3363 Berger-1952

Berger, Curt
Copenhagen U. (Denmark)

THE INFLUENCE OF STROKE WIDTH UPON THE LEGIBILITY (THRESHOLD OF RECOGNITION) OF SOME NARROW NUMERALS OF VARYING HEIGHT

Acta Ophthalmologica, 30:4 (1952) 409-420, 21 refs.

Problem: "(S)tudy the influence of stroke-width upon the legibility of narrow numerals '0' and '5', . . . while changing their height . . . ." (p. 409)

Procedure: The following two different stroke-widths were used for each of the digits 0 and 5: 0.1 and 0.25 millimeters. For each stroke-width, each symbol had a height of 2.5, 4.0, 5.5, 7.0, or 8.5 millimeters. Width was held constant at 1.0 millimeters for all 10 variants of each symbol. "The method used (seven subjects, monocularly, and) was described in detail in . . . (Berger-1948). . . (p. 409) The distance between the eye of the observer and the test-objects was used as the measure of 'legibility', or 'threshold of recognition' . . . . These two terms (were) used synonymously. . . The intensity of light on the fixed adaptation-screen and the movable screen, carrying the test-objects was 58 foot-candles during the first part of the experiments. Then all the experiments were repeated at about . . . 28 foot-candles . . . ." (p. 411)

Result: "Increasing the retinal height (equivalent to visual angle?) from about 300 . . . to 1300 (seconds of arc) had no significant influence upon the recognition of any of the 0's used. Contrary to this, an increase of retinal height of the numerals '5' from 300 . . . to 600 (seconds of arc) increased the threshold of recognition significantly, namely between 17 . . . and 30 (percent). Further increase of height had no influence upon their legibility . . . Decrease of stroke-wi(d)th . . . increased the legibility of the 0's around 14 (percent), while a similar change . . . did not affect the . . . 5's. . . It is suggested, that the limiting factors in the case of the 0's (were) mainly the spatial distribution of active units in the cross-section of their foveal image, double-line and single-line resolution, while in the case of the 5's mainly the displacement threshold decide(d) recognition. . . (T)he results (were) correlated to . . . effects reported by other(s) . . . ." (p. 419)

* * *

3270 Berger-1956

Berger, Curt
Copenhagen U. (Denmark)

GROUPING, NUMBER, AND SPACING OF LETTERS AS DETERMINANTS OF WORD RECOGNITION

Journal of General Psychology, 55:2 (October 1956)
215-228, 12 refs.

Problem: Determine "the effect (of) number (and) spacing of differently grouped constituent letters upon (the distance threshold of recognition) of words and nonsensical letter-groups." (p. 215)

Procedure: "The test objects consist of (capital or lower-case) letters of two type-faces REGAL and WEISS, 10 points, printed isolate(d)ly or in groups black on white (reflection coefficient 2.5 percent for black and 78 percent for white). The following words were used:

| | | | | | |
|---|---|---|---|---|---|
| Group 1: | net | nest | ernst | arrest | |
| Group 2: | sad | sand | stand | strand | |
| Group 3: | AT | SAD | SAND | STAND | STRAND |
| | | STRANDRET | | STRANDTEATER" (p. 215) | |

The following letter spacings were used for "word" groups: 0.5, 1.0, 1.5, 2.0, 2.5, 4.0, 5.0, 7.0, 8.0, 12.0, and 20.0 millimeters. When single letters (A, D, E, N, S, or T) were presented, they were in groups of 1 to 7 of the same letter and spaced at 4.0 millimeters. "The apparatus (used) has been described in . . . (Berger-1948). . . The distance threshold of recognition . . . (was) defined as that distance from the eye which is the mean of the distance between eye and test object, at which the test object can just be recognized (Threshold I) and the distance, at which the test object can no longer be recognized (Threshold II). . . All experiments (were) performed monocularly with three or four normal subjects . . . (T)he test object (was) observed . . . while moving." (p. 217) Illumination was 2.0 Lux (retinal).

Result: The following differences had an influence on the "distance threshold of recognition:"

1. Groups of isolated letters were arranged as follows: best - D, N, and d, n; average - T and t; least - A, S, E, and a, s, e.
2. Isolated capitals were approximately 13 to 24 percent better than isolated lower case letters.
3. The REGAL type-face was 9 to 21 percent better than the WEISS.
4. The threshold* "of words of equal number and spacing of letters (were) proportional to the average (threshold) of their constituent letters. . . (,) of closely spaced words down to 20 per cent less, . . . (and) of optimally spaced words up to 60 per cent higher than the average (threshold) of all single letters, tested isolate(d)ly." (p. 227)

5. The threshold "of words increase(d) with increasing space between single letters up to a maximum (of about 3.25 millimeters), which (was) above average letter-width (letter-width ranged from T = 2.35 to D = 2.70 millimeters)." (p. 227)
6. The threshold "of words increase(d) with the number of constituent letters, apart from the effect of spacing. The limit of this effect (was) not reached by use of up to 11 (or) 12 letters in a word." (p. 227)
7. The threshold "of nonsensical letter combinations (decreased) significantly from (the threshold) of words . . . ." (p. 227)

The following had no significant influence on the "distance threshold of recognition:"

1. The "(f)orm of words due to differences of grouping of constituent letters (Gestalt - sic) ha(d) no specific influence . . . ." (p. 227)
2. The determination of "optimal spacing (of 3 to 4 millimeters was) independent of the (word) length . . . ." (p. 227)
3. In ascertaining the lesser threshold for nonsensical letter combinations vs. words, the nonsense "words" showed basically the opposite or no effect of number of constituent letters upon (the threshold)."

"The (following) practical and theoretical significance of the results (were) discussed.". .(:) (p. 227)

1. "Determinations of distance thresholds of recognition deal with one aspect of the complex problem of 'legibility,' especially important for signs on highways and streets, for advertising displays as well as traffic regulations." (p. 224)
2. Determinations of distance thresholds of recognition should also be "useful for differentiating different type-faces and
3. "for determination of specific characteristics of structure, spacing, and number of letters in a word, decisive for their recognition at the longest possible distance from the human eye." (p. 224)
4. "Studies of the dependence of (the distance threshold of recognition) on structural details (such) as stroke-width, width and height of <u>single</u> letters, are a prerequisite for developing lettering to be read at optimal distances from the eye." (p. 224 and 226)

The following conclusions were drawn from the results:

1. "Perhaps the most important theoretical conclusion . . . is the fact that 'grouping' of letters as such has no effect on (the threshold) of words. This is not only contrary to Gestalt-concepts, but seems also to contrast with everyday experience." (p. 226)
2. "Spacing between single letters (up to an optimum) and number of letters in a word evolve as new and important determinants of (the threshold). The basic physiological function involved is the resolution threshold of the retina. . . The . . . effect on (threshold) of <u>number of letters in a word</u> appears to be central in nature. . . (and) is limited to sensible words." (p. 226)

Thus, in general, <u>the distance threshold of recognition</u> "<u>of words</u> (<u>is</u>) <u>affected by a partly unconscious process</u>, <u>improved by the number of letters in a word</u>, <u>but decreased by</u>

consciously focussing attention upon the single constituent letters of words." (p. 227)

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* - "Threshold," or "the threshold," unless otherwise qualified, as by an adjective, is taken to mean "the distance threshold of recognition." It is referred to by the author as Dtr throughout the paper.

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3447 Berger-1960

Berger, Curt

VISUMETER (A DEVICE FOR EXPERIMENTAL RESEARCH ON THE LIVING HUMAN EYE AND FOR A MORE ACCURATE DETERMINATION OF RESOLUTION)

Die Farbe, 9:1/3 (1960) 63-72, 23 refs.

Abstract: "The Visumeter is a device designed for experimental work on the eye's sensibility (sic) to differences in luminance, color, form, and time, (and) further to investigate the retinal resolving power, legibility and irradiation." (p. 63) A well-labeled drawing of the apparatus is provided. This is a descriptive paper with no experimental or detailed construction data.

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3445 Berger-1961

Berger, Curt

DIE LESBARKEIT FARBIGER KENNUMMERN (THE LEGIBILITY OF COLORED SIGNAL NUMERALS)

Die Farbe, 10:5/6 (1961) 3-19, 32 refs.

In German, with English summary

Abstract: Numerals were redesigned, as shown in the article's illustrations, with a resulting legibility improvement of approximately 18 percent. A standard curve was developed to provide the optimal character height for any legibility distance, for both black characters on a white background and white characters on a black background. "The influence of 22 colour combinations on the legibility (was) studied, with special allowance made for the variation of hue." (p. 3) The best color combination for distant legibility was black on yellow; the poorest combination was yellow on white.

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Betts-1942

3353

Betts, Emmett A.

Pennsylvania State U., University Park

A STUDY OF PAPER AS A FACTOR IN TYPE VISIBILITY

The Optometric Weekly, 33:9 (April 9, 1942)

229-232, 45 refs.

Problem: ". . . (S)tudy the effect of paper color, or tint, upon visibility in a controlled light situation." (p. 2)

Procedure: "A new type of paper, with the trade name Facilex, has been developed by the Fitchburg Paper Company for printing school textbooks. This paper was developed to increase 'ease of reading' under varying lighting conditions. The cream tint, special (calendering), and revised manufacturing process were believed to contribute to 'ease of reading'." (p. 2) In testing it, a factorial experiment involved 26, randomly selected, sixth-grade, public-school students, who viewed four targets each of 16 different types of paper,* including the Facilex. "Typographical specifications for the total (of text type) follow: type page---23 x 36 picas, type face---MONOTYPE NO. 157-CENTURY OLD STYLE with long ascenders and descenders, text---in 12 point leaded 4 points, head note on page 61 in 11 point leaded 2 points, story head 12 point NO. 157 caps, section head 11 point NO. 157 caps, and running head 11 point NO. 157 italic caps and lower case." (p. 3) In this threshold experiment, 1664 readings were taken using the Luckiesh-Moss Visibility Meter (laboratory model). Two sittings were used for each subject. Those subjects with reading handicaps were permitted to spell rather than read the words. Reading distance was 14 inches. Illumination was twenty foot-candles of diffused artificial light on the target.

Result: "Within the limits of . . . data, the following conclusions appear to be valid:

1. "For practical purposes, the experimental paper, Facilex, appears to produce as much type visibility as the 'white' paper now used in basal readers.
2. "The tinted experimental paper, Facilex, appears to produce substantially better results than the other 'white' experimental paper . . . used in this study." (p. 4)

Preliminary remarks in this study suggest that the following are additional important considerations:

1. "One of the classic studies on the readability of books was reported by Gray and Leary." (p. 1) They compiled the following factors as influencing readability: Format or mechanical features; size of book, number of pages, quality of paper, kind of type and printing, length of line, margins, general appearance of page, binding, and illustrations. General features of organization; title of book, chapter divisions, paragraph divisions, and reference guides. Style of expression and presentation; vocabulary, sentences, paragraphs, chapters, attitude of author, method of presentation, style of presentation, and stylistic devices. Content; theme, nature of subject matter, and unity of content. Subjectively, the two major factors that seem to have the greatest influence were found to be "content" and

"style of expression and presentation", each accounting for approximately one-third of the solution to the problem of readability.

2. "Visibility" is distinguished from "readability" by Luckiesh and Moss in the following manner: "Visibility is a term used . . . 'to denote the intensity of a psychophysical stimulus which evokes visual perception and discrimination.' Readability is used 'to express the integral effect of physical factors which influence ease of reading'." (p. 1)
3. The following experimental test criteria are discussed by the authors: rate of reading, rate of involuntary blinking, ductions, heart rate, nervous muscular tension, pupil size, and visibility as measured by the Luckish-Moss Visibility Meter. "In general, certain conclusions have been reached regarding the use of the above criteria: 1. The criterion should reveal small increments or decrements of change. For example, Luckiesh and Moss found that rate of blinking was a more sensitive 'indicator of readability' than normal rate of reading. 2. The criterion should be one that can be evaluated in terms of the individual's compensatory abilities." (p. 2)

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* - "Nine publishers (Bobbs-Merrill Company, Houghton Mifflin Company, Johnson Publishing Company, Lyons and Carnahan, Row, Peterson and Company, Scott Foresman and Company, Silver Burdett and Company, Webster Publishing Company, and the John C. Winston Company) of elementary school basal readers . . . suppl(ied) fresh stock for printing the targets. With the exception of two samples submitted by the Fitchburg Paper Company, the paper was the same as that used in the basal readers published by the co-operating companies. . . The printing . . . was done on one press of the American Book Company. Plates for pages 61, 62, 63, and 65 of Friendly Hour Readers, Grade 5, were used." (p. 3)

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3364 Birren-1957

Birren, Faber

SAFETY ON THE HIGHWAY: A PROBLEM OF VISION, VISIBILITY, AND COLOR

American Journal of Ophthalmology, 43:2

(February 1957) 265-270, 2 refs.

Problem: Study the interrelation between color/shape and message legibility on highway warning, regulatory, guide signs.

Procedure (study I): "(A) conventional stop sign in red (background) and white (letters and border) was placed in a prominent location with the letters rearranged to read TOPS. . . After passing the sign, 100 drivers were questioned.". . (p. 267) as to whether they noticed anything unusual in passing the sign.

Result (study I): "Under the assumption that a stop sign registers primarily for its color and shape, it could be expected that few persons would note anything unusual. . . Of (the

drivers questioned), 86 percent (overall---87 percent habitual drivers along the road and 79 percent strangers) admitted that the word TOPS had been overlooked. . . The reason is simple enough, for visual reaction to color is involuntary, while words require deliberation." (p. 267)

Procedure (study II): "(T)he general subject of legibility was reviewed. . . (F)our reflectorized signs (white on red---word WON, black on yellow---letters O, W, and backwards N, black on white---word NOW, and white on green---word OWN) were prepared, using eight inch letters on an octagonal panel. The test was designed to check relative legibility, and to interpret the data in terms of realistic driving speeds." (p. 267) "Several" observers were utilized.

Result (study II): "(A)ctual legibility (averaged among the observers) was as follows . . .": (p. 268)

| sign | day-rank and distance (feet) | night-rank and distance (feet) |
|---|---|---|
| black on white | 1---404 | 3---316 |
| white on red | 2---361 | 4---312 |
| black on yellow | 3---358 | 1---341 |
| white on green | 4---358 | 2---337 |

"On an average the signs were legible on night driving at 88 percent of the day viewing distance. . . In the . . . test described . . . a few significant figures . . . would apply if a driver were proceeding at . . . 50 (miles per hour).

1. "During the day, the threshold points of the black on white . . . and the white on green . . . (were) 0.627 seconds apart---a mere heart beat!
2. "At night, the threshold points of the black on yellow . . . and the white on red . . . (were) only 0.395 seconds apart!

"In both instances the time element . . . (was) less than the .75 second 'reaction time' so often mentioned . . . From the above facts it is perhaps fair to state that slight differences in the legibility of traffic signs are of no great consequence. If black on white has minor advantage, it would be impractical to keep adding more and more combinations of it . . ., because clear identity and differentiation through color would be lost and a meaningful code sacrificed." (p. 268-269)

Result (general): The following general observations were made (not necessarily supported by the above):

1. "(C)olor in vision . . . commands attention, arouses interest and pleasure, and seems to work its way deep into consciousness. . . In the supermarket, for example, it is conceivable that all packages in black and white would be quite visible. Yet color is introduced for purposes of outright attraction." (p. 265 & 266) In "studies of black and white . . . versus color advertisements, fully 50 percent greater readership and memory retention have been demonstrated." (p. 266)

2. "(G)ood legibility is a . . . function of size and contrast. In . . . conditions of extreme brightness . . . , white on black holds certain advantages because it tends to control glare. . . In darkness or dim light, black on white is desirable because it sets up a bigger target and is easier to seize upon visually." (p. 266)
3. "(T)ests of visibility and legibility . . . conducted under controlled conditions in which (a) the observer's attention is fixed, and (b) he approaches the sign slowly. . . (are) not very typical of average driving in which there are countless distractions, high speed, and a wandering eye and mind. . . Therefore, before the sign serves a practical purpose at all, it must itself be found and located! . . Having this need in mind, the value of color begins to loom large." (p. 266)
4. "(R)esearch (by the railroads) led to the accepted fact, that in recognition red was the color of first importance, then green, then yellow, with white fourth. . . (W)hile white might be . . . of high visibility, it tended to lack impulsive attraction and psychologic interest. . . (T)he standards . . . adopted later in the red, yellow, and green traffic signal . . . (were) the same as those of the Association of American Railroads." (p. 267)

"The four color schemes used in (study II) are those . . . commonly found on traffic signs. All have good visibility. . . (a)nd . . . should be reflectorized or illuminated . . . to assure general high brightness at night and a uniform day-night appearance." (p. 269)
Comments concerning individual combinations were as follows:

1. (white on red warning signs) "The use of red solely for (STOP sign) identification is . . . sound, for red is a color of high recognition and impulse attraction (although it may lack distinction to a low percentage of color-blind men)." (p. 269)
2. (black on yellow warning signs) "(T)he choice could hardly be improved. . . (Y)ellow has more impulse attraction than achromatic white. . . (,) is less likely to show glare. . . (, and) reflects in the high visibility region where areas, forms, and images are sharply focused." (p. 269)
3. (black on white regulatory signs) The "combination, though commonplace, is probably satisfactory. . . (H)owever, too much use . . . may offer certain drawbacks of repetition and monotony." (p. 269)
4. (black background for highway signs) "A thorough investigation . . . would seriously question black as a suitable color for . . . backgrounds---despite the high legibility it gives to white legends or characters. . . It affords . . . no stimulation of the . . . retina . . . , it is emotionally negative, . . . (and) it is most difficult to focus." (p. 269)
5. (white on green guide signs) "This would apply to directional signs, destination signs, distance signs, and route markers . . . . If red is for stop, yellow for caution, white for regulation or information, green would be a likely symbol to keep . . . moving . . . . Obviously the green should be reflectorized so that its night symbol would be identical with its day likeness (sic). . . Green as a color is second in recognition only to red. . . (a)nd . . . it is emotionally tranquil rather than impulsive . . . ." (p. 270)

Relative to color in general, the following overall observations were made:

1. "Maria Rickers-Ovsiankina writes, 'Color experience . . . is . . . a much more immediate and direct sense datum than the experience of form. . .'" (p. 270)
2. "(T)he useful 'spectrum' for traffic purposes is extremely limited. The number of clearly distinguishable and different colors is few---red, green, yellow, white. Added to these might be orange, pink, blue, purple . . ., and the list is practically exhausted. . . (O)range and pink might be introduced where high impulses are desired for some new and vital purpose. The blue and purple, however . . . are difficult to focus and tend to form a blurred image . . . ." (p. 270)

* * *

2142 Bitterman-1945

Bitterman, M. E.
Cornell U., Ithaca, N. Y.
HEART RATE AND FREQUENCY OF BLINKING AS
INDICES OF VISUAL EFFICIENCY
Journal of Experimental Psychology, 35:4
(August 1945) 279-292, 41 refs.

Problem: Determine the effect of type size and illumination level on heart rate, frequency of blinking, and level of performance, with a view to using these as indices of visual efficiency. Compare the results with those of previous investigators.

Procedure: "Continuous electromyographic recordings of cardiac and eyelid activity were made as (subjects) performed visual tasks under" (p. 291) varied conditions in two experiments. The first experiment, using 14 subjects, "was designed to provide data on the variation in heart rate, frequency of blinking and level of performance with size of type." (p. 283) Subjects, who were undergraduate psychology students, naive to the experiment, and had normal vision, sat in comfortable chairs (with writing boards), in a temperature- and humidity-controlled room, where their task was to compare (in predetermined time periods) paired names and number-groups in the Minnesota Vocational Test for Clerical Workers. The Test was reproduced in two type sizes (approximately 6- and 10-point height) onto high-quality, non-glossy, white paper, and received a constant illumination level of 3 foot-candles. Experimenters tested for both accuracy and speed. The second experiment, which made illumination level (rather than type size) the variable, utilized 10 subjects (similar to those in the first experiment) under nearly identical conditions to the above, except for the following: stimulus material was The Battle is the Payoff, which the subjects "were given to 'settle down and enjoy . . .'; (t)he book was printed in 10-point type on non-glossy paper. . .; (h)alf of the subjects read under illumination of three foot-candles on the first day and 91 foot-candles on the second. . .; (t)he others read first under the higher level. . .; and (t)he illumination was diffuse and produced no appreciable glare." (p. 287) Performance level was not measured in the

second experiment.

Result: "Although level of performance differed significantly for the two sizes of type employed in the first experiment, patterns of blinking were very similar under the two conditions. . . In the second experiment, blink rate was . . . higher during work under the more intense illumination, but was unrelated to (subjects') preferences in the matter. . . (p. 289) Even if average trends had been significant, . . . the individual variation would would indicate that many factors play a part in determining the pattern. . . (p. 290) It is clear that rate of blinking can have little value as an index of visual fatigue or effort. . . (p. 289) With reference to heart rate, . . . (d)uring relaxed reading the heart rate shows a greater tendency to decrease with the passage of time under low as compared with high illumination. It is not justified, however, to assume that cardiac deceleration is a function of increased expenditure of effort. . . (p. 290) (T)he results of the first experiment make untenable the position that visual effort produces cardiac deceleration." (p. 291) Hence, "(t)he results do not support the conclusions of Luckiesh and Moss with respect to the value of heart rate and frequency of blinking as indices of the ease of visual work." (p. 291) In addition, "(t)he findings of the first experiment support the position of Paterson and Tinker that under suitably controlled conditions performance tests afford a reliable approach to problems of visual efficiency. . . It is recognized . . . that studies of visual efficiency must, by definition, involve some measure of the cost of work. The results of other (previous) investigations indicate that further experiments with muscular tension might profitably be undertaken." (p. 291)

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3344 Bitterman-1946a

Bitterman, M. E. and Soloway, Esta
Cornell U., Ithaca, N. Y.
THE RELATION BETWEEN FREQUENCY OF BLINKING AND EFFORT EXPENDED IN MENTAL WORK
Journal of Experimental Psychology, 36:2
(April 1946) 134-136, 13 refs.

Problem: Determine the possibility "that there is a tendency for blinking to increase with effort in so-called mental work." (p. 134)

Procedure: "The plan of experiment was similar to that outlined in a previous communication (see Bitterman-1945) . . . (p. 134) dealing with the effect of type size on frequency of blinking. In the present experiment the variable was distraction produced by the continuous playing of a record of a man's voice reciting groups of numbers from one to ten digits in length. . . (at an) intensity level (of) approximately 60 (decibels). Each of . . . 10 (subjects) worked (during periods of distraction and of complete silence) . . . on

reproductions of the Minnesota . . . Test . . . under illumination measured as 10 foot-candles at the working surface. . . The method controlled practice, fatigue, adaptation to the level of illumination, temperature, and humidity. The procedure of obtaining performance scores and continuous electromyographic tracings of cardiac and eyelid activity was the same as in the previous experiment." (p. 135) Performance was measured by both speed and accuracy.

Result: "Although there was no significant difference in performance under the two conditions of work, the results for heart rate justify the assumption that the distraction employed was sufficient to necessitate increased effort on the part of the (subjects). The negative results for blink rate indicate, therefore, that this index bears no relation to the difficulty of the task. Since it has generally been found in experiments of this kind that distraction is accompanied by increases in muscular tension, it must be concluded that there is no tendency for these tensions to influence frequency of blinking." (p. 136) In comparing the present results to those of (Bitterman-1945), "(i)t might be argued that such (previous) results cannot lead to any conclusion with respect to the validity of blink rate as a measure of effort because it may be that the lower performance scores achieved with smaller type indicated that effort did not increase. The present results remove the basis for this argument." (p. 136)

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2145 Bitterman-1946c

Bitterman, M. E. and Soloway, Esta

FREQUENCY OF BLINKING AS A MEASURE OF VISUAL EFFICIENCY: SOME METHODOLOGICAL CONSIDERATIONS

American Journal of Psychology, 59:4 (October 1946) 676-681

Minor Studies from the Psychological Lab. of Cornell U., 93.

Problem: "(D)uplicate the essential conditions of . . . (a)n experiment by Luckiesh and Moss on the relation of glare to frequency of blinking . . . and . . . introduce variations relating to the influence of (a) method of recording, (b) kind of work performed, and (c) S's (subjects') knowledge of what was being measured." (p. 677)

Procedure: Four groups of ten subjects each participated in a reading experiment having the following group variables:

| group | recording | work performed | knowledge |
|---|---|---|---|
| I | electromyographic | normal reading | without |
| II | direct observation | normal reading | without |
| III | electromyographic | normal reading | with |
| IV | electromyographic | speed test | without |

In all cases, the material read was printed in 10-point black type on non-glossy white paper. Subjects sat in a comfortable chair equipped with an adjustable writing board. Overhead illumination provided 10 foot-candles on the working surface and a brightness-

ratio (ratio of the brightness of the reading material to that of the surround) within the range of 1:1 to 5:1. Glare, when introduced, was provided by a separate single lamp "at an angle of $20^{o}$ with the line of regard." (p. 678) Blink rate was recorded by the techniques indicated above. Normal reading work utilized H. G. Wells' Outline of History, while the speed test used an adaptation of the Minnesota Vocational Test for Clerical Workers. All subjects had knowledge that "various physiological processes" were being measured, but the subjects in group III were specifically told that blink rate was being measured, but were not told that glare was involved.

Result: "None of the differences . . . (in the m)ean frequencies of blinking for the various groups . . . under conditions of glare and no glare . . . proved to be significant. . . (p. 679) Questioned . . ., 19 of the 40 (subjects) reported they considered the glare a source of distraction or annoyance. . . The results of the experiment by Luckiesh and Moss . . . are not confirmed by those here presented. . . (p. 680) (T)he value of frequency of blinking as an index of visual efficiency (sic) must at the present time be denied." (p. 681)

* * *

2146 Bjelland-(1963)

Bjelland, H. L.
National Cash Register Co., Hawthorne, Calif.
DATA DISPLAY STUDY
First Quarterly Rept., 1 Dec 62-Mar 63
Rept. no. 1, 56 p.
Contract DA-36-039 SC-90855

Problem: Determine the prospective utility of Photochromic techniques in data display systems, including the parameters necessary for character generation and display.

Procedure: The following author abstract shows the tone of the report: "State-of-the-art in Photochromic Displays is discussed. Comparisons are made of Army Artillery and Army Intelligence display parameters. Two possible techniques of advancing the state-of-the-art of the photochromic display technology are described: one electromechanical; and one electronic, employing a CRT (cathode-ray tube) for writing on photochromics." (p. 1)

Result: "The parameters for a large-screen Intelligence display (formulated in discussions with Army Intelligence representatives)" (p. 4) are (selectively) as follows:

1. "The number of basic alphanumeric and graphic symbols that would satisfy present and future requirements is 100 to 125.
2. "Basic unit symbol size would be 1-1/4 inch wide by 3/4 inch high.
3. "Symbol line width would be 1/32 inch.

4. "Letter and number sizes would be approximately 7/32 inch.
5. "A typical symbol group consists of an average of 15 symbols, including alphanumerics.
6. "Screen size would be 5 ft. by 7 ft. (p. 4)
7. "Viewing angle would be 45 degrees, with respect to perpendicular to the screen center.
8. "Anticipated group viewing distance is 10 ft. to 12 ft.
9. "Screen surface should permit grease pencil notations.
10. "Data would be projected on the screen from the rear.
11. "Ambient light level would range from moderate to that of a well-lighted room.
12. "Resolution should be greater than 1000 by 1000 lines. (p. 5)
13. "Colors might be used to distinguish categories. Red, yellow, green, blue, black and white are used.
14. "A cursor and a method of highlighting new data for approximately 30 seconds is desirable. (p. 6)

"Specifics of the Artillery Display (derived from meetings with Army Artillery personnel) are listed in the following paragraphs:

1. "Color is desired for background map projection.
2. "Colored symbols are not necessary; symbology (listed in Field Manual FM21-30) is acceptable.
3. "The ability to change the orientation of symbols is desirable (and possibly necessary).
4. "Typically, a 40 by 40-inch screen is desired. Screen sizes might be as large as 5 or 6 feet square.
5. "Display should operate in ambient light ranging from moderate to that of a well-lighted room. . . (p. 7)
6. "Means should be provided to easily generate and produce a transparent overlay . . . . Overlay should contain only dynamic data. . . (T)he overlay should measure 40 by 40 inches . . .
7. "It is desirable to highlight new data until operator takes action." (p. 9)

In a comparison of both needs, the following data are pertinent:

| characteristic | intelligence | artillery |
|---|---|---|
| symbols per group | 15 typical | 8 to 10 typical |
| unit symbol size | 1-1/4 by 3/4 in. | 3/8 inch |
| line width | 1/32 inch | 1/32 inch |
| alphanumeric symbol size | 7/32 inch | 3/16 inch |
| screen projection | rear | rear or front |
| resolution | 1000 by 1000 lines | 1000 by 1000 lines |
| color data plot | red, yellow, green, blue, black, white | not required |
| highlight new data | desirable | desirable |

(above from p. 10)

Bjelland-(1963)

Two suggestions made by the author are as follows:

1. "It is suggested that symbol sizes be expressed as a percentage of screen size. The symbol sizes listed in (the above table) range from 1 to 1.5 percent of screen size. . . (p. 11)
2. "(B)ased on increased cost, decreased reliability, and increased complexity, it is preferable not to provide a dynamic color plotting capability. Instead . . . the suggestion is made that consideration be given to special symbology to differentiate the desired categories, e.g., double lines, dotted lines, or simply a meaningful symbol such as F or U superimposed on the target to distinguish between friendly or unfriendly." (p. 13)

In a preliminary system design, the dimensional specifications for a typical character were as follows:

1. "height = 1.5 (percent) of display size
2. "line width = 0.15 (percent) of display size
3. "repeatability width = 1/4 of line width" (p. 42)

"Three character generation techniques have been considered: shaped beam, line trace, and dot matrix. . . Because all of the three . . . would probably be satisfactory, no further investigations were conducted (in this area)." (p. 46)

* * *

2148 Blackhurst-1927

Blackhurst, James H.

INVESTIGATIONS IN THE HYGIENE OF READING

Baltimore, Warwick and York, 1927, 61 p.

Problem: (1) Give an historical review of legibility and readability experimentation. (2) Determine, for the readability of textual material, the effect of margin on the first grade, and size of type, length of line, and leading on the first four grades of school children.

Procedure: The results of previous experimentation is reported on below. The experimentation here involved four tasks. Constants were as follows:

1. Subjects - of normal age for the first through the fourth grades, except in the task concerning margins, in which only first grade students were used.
2. Environment - pleasant surroundings, quiet and well lighted room, no disturbances, natural lighting from behind subject, and experimenter out of visual range of (behind) subject.
3. Task - textual reading assignments were made in a random fashion, and were read out-loud with subject standing.
4. Test criteria - speed and accuracy.

Experimental variables were as follows:

1. Task one (size of type) - The following point sizes were used: 8-, 10-, 12-, 14-, 18-, 24-, and 30-point. A total of 190 subjects participated in a total of 910 readings.
2. Task two (length of line) - The following approximate line lengths were used: 55, 80, 90, 100, 120, and 140 millimeters. 210 subjects participated in 1296 readings.
3. Task three (leading) - The following leading was used: set solid, 1-, 2-, 3-, 4-, and 10-point. 156 subjects participated in 588 readings.
4. Task four (regularity of margins) - The following margin formats were used: both regular, left regular and right irregular, and both irregular. 36 subjects participated in 108 readings.

Result: A summary of the conclusions made from the author's experiments is as follows:

"Size of Type: Eighteen-point type (height of small letters 2.75 mm.) is more readable in all the first four grades than type which is smaller. Twenty-four-point type offers about the same reading difficulty in the second grade as does eighteen-point type. In the first grade twenty-four-point type is more readable than that which is smaller or larger. The question of its use in this grade should be one of expense rather than desirability.

"Length of line: The most desirable length of line for the first four grades lies around 100 millimeters.

"Leading: There is no justification for more than 1.33 millimeters of leading in the third and fourth grades. The studies in the first and second grades are inconclusive.

"Margin: There is no advantage to be gained in the first grade in making the right margin (margin on reader's right) irregular. There is an advantage to be gained in making the left margin irregular." (p. 61)

Pertinent statements derived from the historical summary are as follows:

1. "Plateau . . . in . . . 1835 said that it took a certain length of time for an impression to be produced by light. Flick . . . confirmed the opinion . . . . Bruecke found this time to be .119s decreasing in arithmetical progression as the intensity of light increased in geometrical progression." (p. 11)
2. "The first to write and experiment with the problems of the hygiene of reading definitely in mind was Doctor Emele Javal whose work was reported in "Essaies sur la physiologie de la lecture" 1878-9, Javal attempted to work out the order of legibility in the letters, which he tested by the distance at which they could be read." (p. 12)
3. "Weber . . . found that . . . letters greater in size than 2 mm. retarded the

speed of reading. He set 1.5 as the minimum. He, also, advanced the theory . . . that lines 14 to 15 cm. in length could be read more readily than those shorter or longer." (p. 12)

4. "Cohn believed that 100 mm. (4 inches) was the maximum length of line advisable and 90 mm. (3.6 inches) the best length of line where the small letters were 1.5 mm. in height. If larger letters were used Cohn believed a line of 110 mm. possible." (p. 13)

5. Cattell "found that the time a . . . light must work upon the retina was different for the several colors, the retina being most sensitive to orange and least sensitive to violet. . . (I)n the case of one color following another the time necessary for the recognition of the second was increased from about two and one-half to fifteen times its usual length." (p. 14)

6. "With respect to the effect of the intensity of light upon the time of recognition Cattell makes the following statement: 'The portion of the curve I have investigated follows the formula,

$$t = c \log i(+ c')$$

in which t is the necessary time and i the intensity of the light; that is, the time colored light must work on the retina in order that it may be seen, increases in arithmetical progression, as the intensity of the light decreases in geometrical progression.'" (p. 14)

7. "(I)n determining the time the light reflected from a letter or a word must work upon the retina in order that it may be distinguished. . . (Cattell) concludes as follows: '. . . not only are some types harder to see than others but different letters in the same alphabet are not equally legible . . . The order of distinctness for the small letters . . . follows: d k m q h b p w u l j t v z r o f n a x y e i g c s . . . As in the case of capital letters, some letters are hard to see (especially s, g, c, and x) owing to their form; others are misread, because there are certain pairs and groups in which the letters are similar. A group of this sort is made up of the slim letters i j l f t, which are constantly mistaken the one for the other.'" (p. 14-15)

8. "Cattell would use a different character for 1 (one) and do away with the dot over the i (eye)." (p. 18)

9. "Sanford tested legibility of letters using as . . . criteri(a) . . . the distance . . . and . . . time test(s)." (p. 15) The following results were obtained (in descending order of legibility):

   distance - first method:

   m w f p q r j v k b y h d g x a i l u s t n e c o z

distance - second method - subject H:

w m j f v y q p d h b r x l g u k n z o a t c s e i

distance - second method - subject M:

m w y q p h d k b v x j u n r l f g t c o s a z i e

distance - second method - subject J:

y m f j w v g q p b x r d h n t k i u o z l a s c e

time:

m w d q v y j p k f b l i g h r x t o u a n e s c z

". . . by a strange bit of perversity several of the worst letters are those most frequently used. This is most strikingly true of the letter e. The group most prone to confusion was . . . f j i l t. Small s is more likely to be confused with these letters than with a or z. (sic) . . . (I)n the words of Sanford: 'With most of the letters breadth is rather of more advantage, other things being equal, than length for it gives some visibility to their internal spaces; . . . Javal is undoubtedly right in preferring short broad letters to long narrow ones.' The rounded effects of letters like s proves confusing; while the angular effects of letters like z ma(k)e them more easily distinguishable." (p. 17-18)

10. Dearborn concluded the following: "'The rate of reading depends upon the ease with which a regular rythmical (sic) movement is established. Uniformity of line length aids . . . in establishing rhythmical eye-movements. Lines should be from 75 to 85 mm. in length.'" (p. 19)

11. "Dockeray . . . studied the relative legibility of letters . . . The findings . . . did not well agree with those of Sanford. For example, . . . n, which appears near the first in Sanford's results, is found to be nearly the poorest . . . . There is agreement in that both found broad letters to be the most easily read; while the tall thin letters were the least satisfactory." (p. 19-20)

12. "Roethlein studied the relative legibility of some fifty faces of type, comprimising some thirty ordinary faces together with such variants as italics, bold, condensed, expanded and various combinations . . . The capital letters which proved to be the most distinguishable were the JENSEN OLD STYLE (a broad letter with thin lines). the AMERICAN TYPEWRITER letters were the most difficult to distinguish. . . The optimal heaviness of face seems . . . to lie in a mean between the bold faces and such light faces as SCOTCH ROMAN and CUSHING MONOTYPE." (p. 20-21)

13. Gilliland, using short reading specimens in 3-, 4-, 6-, 9-, 12-, 24-, 36-, 54-, and 90-point type, concluded "that size of type is not an important factor in the reading process so long as the size of type is not extreme either in the direction of small or large type." (p. 22)

14. "The Committee on the Standardization of School text books . . . set up the following norms (in 1911) as regards text books:

a. "The paper should be unglazed, free from shine, and opaque.

b. ". . . The maximum of safety (for line length) is 90 mm. and 60 mm. to 80 mm. is better.

c. "The margin should be sufficient so that the eye, in the backward movement does not swing off the paper; and the inner margin should be wide enough so that the inner end of the line is not obscured by the curvature of the paper.

d. "The sizes of type should be as follows:---1. Adult standard---(i) The height of the small letters should be 1. 5 mm. (ii) The width of the vertical stroke should be . 25 mm. (iii) The space within the letters should be . 5 mm. (iv) The space between the letters should be . 50 to . 75 mm. (v) The space between the words should be 2 mm. (vi) The leading should be 2. 5 mm.

2. Standards for children are as follows:

A. First grade---(i) The height of the small letters should be at least 2. 6 mm. with the other dimensions in proportion. (ii) The width of the vertical stroke should be from . 4 mm. to . 5 mm. (iii) The space within the letters should be from . 8 mm. to . 9 mm. (iv) The space between the letters should be about 1 mm. (v) The space between the words should be about 3 mm. (vi) The leading should be 4 mm. to 4. 5 mm.

B. For the second and third year the standard may be reduced slightly, but the letters should not be less than 2 mm. in height, and the leading should be 4 mm.

C. For the fourth year height and leading should not be less than 1. 6 mm. and 3 mm., respectively. It would be better to retain the standard of the fourth year through the sixth year." (p. 22-23)

15. "(A) committee of the British Association for the Advancement of Science" recommended the following standards for school books:

| age | height * | length * | space * | lines * | measure * |
|---|---|---|---|---|---|
| 7 | 3. 5 mm. | 96 mm. | 6. 5 mm. | 10 | |
| 7 to 8 | 2. 5 mm. | 72 mm. | 6. 4 mm. | 15 | 100 mm. |
| 8 to 9 | 2. 0 mm. | 55 mm. | 2. 9 mm. | 20 | 93 mm. |
| 9 to 12 | 1. 8 mm. | 50 mm. | 2. 4 mm. | 22 | 93 mm. |
| over 12 | 1. 58 mm. | 47 mm. | 2. 2 mm. | 24 | 93 mm. |

* - height = minimum height of faces of short letters

length = minimum length of alphabet of small letters

space = minimum interlinear space

lines = maximum number of lines per vertical 100 mm. (approx. 4 inches)

measure = maximum length of measure of line

16. "Shaw made an analysis of type found in four primers with the following results:" (p. 24) size of type - 2.5 to 3.5 millimeters; leading - 5.0 to 7.5 millimeters.

"The writer made a study of three hundred and twelve elementary school readers published from 1860 to (1921) for the purpose of determining . . . the trend of their typography." (p. 25-30) Results are as follows:

| height of small letters | before 1890 | 1890-1900 | 1900-1910 | 1910-1921 |
|---|---|---|---|---|
| first grade median (mm.) | 2.53 | 2.54 | 2.46 | 2.50 |
| second " " " | 2.09 | 2.19 | 2.18 | 2.32 |
| third " " " | 1.63 | 2.00 | 2.00 | 2.00 |
| fourth " " " | 1.63 | 1.75 | 1.75 | 1.75 |
| fifth " " " | 1.50 | 1.75 | 1.75 | 1.75 |
| sixth " " " | 1.50 | 1.50 | 1.75 | 1.75 |
| length of line | 1890 | -1900 | -1910 | -1921 |
| first grade median (mm.) | 89.00 | 98.00 | 101.41 | 101.00 |
| second " " " | 89.00 | 106.00 | 102.00 | 102.00 |
| third " " " | 84.00 | 94.00 | 97.00 | 102.00 |
| fourth " " " | 89.00 | 93.00 | 103.00 | 101.00 |
| fifth " " " | 89.00 | 96.00 | 102.00 | 97.50 |
| sixth " " " | 88.00 | 94.00 | 97.00 | 101.00 |
| leading | 1890 | -1899 | -1910 | -1921 |
| first grade median (mm.) | 1.90 | 2.41 | 2.78 | 3.12 |
| second " " " | 1.13 | 2.19 | 2.25 | 2.63 |
| third " " " | 1.25 | 1.75 | 2.00 | 2.10 |
| fourth " " " | 1 (sic) | 1.63 | 1.75 | 1.75 |
| fifth " " " | .87 | 1.25 | 1.56 | 1.25 |
| sixth " " " | 1.00 | 1.50 | 1.25 | 1.50 |
| regularity of margins | 1890 | -1899 | -1910 | -1921 |
| (first grade) | | | | |
| both margins regular | 29% | 27% | 13% | 13% |
| both margins irregular | 54% | 46% | 43.5% | 56% |
| left margin regular only | 17% | 27% | 43.5% | 31% |

"In general there was an increase in the size of type" with the passage of time. "The first grade however, (was) an exception. . . (T)ype becomes smaller as we go up the grades from the first to the fourth but at this grade a minimum has been established which remains constant . . . (I)n the case of the length of line . . . there is no exception to the increase (with the passage of time). . . In the books published since 1910 the . . . median length (has been) 101 millimeters. . . Considering the question of leading . . ., there has been a steady decrease in the amount . . . used as we go up the grades from the first to the fifth. . . There was a tendency from 1890 to 1910 to make the left margin regular leaving the right irregular. From 1910 to (1921), however, the tendency has been to make both margins irregular." (p. 25-30)

* * *

3331 Botha-1963a

Botha, B. and Shurtleff, D.
Mitre Corp., Bedford, Mass.
STUDIES OF DISPLAY SYMBOL LEGIBILITY: THE EFFECTS OF LINE CONSTRUCTION, EXPOSURE TIME AND STROKE WIDTH
Rept. no. TM-3515, Jul 63, lv., 11 refs.
Contract AF33(600)-3958
ESD-TDR-63-249; AD-414 323

Problem: "(D)etermine the effects on the legibility of capital alphabetic letters of: (a) two simulated TV rasters with horizontal, linear scan constructions of 11 and 5 lines per letter height and a solid (continuous) construction of infinite lines per letter height, (b) two visual exposure times of 0.03 and 0.003 second, and (c) two letter stroke-widths of 16 (percent) and 28 (percent) of letter height." (p. iii)

Procedure: "Four subjects identified the letters (in alphabets A and B) presented singly (white on black) in a tachistoscope under all combinations of (the above) conditions. Legibility was measured three ways: by information transmitted (in bits), by errors in identification, and by verbal reaction time." (p. iii)

Result: "The results showed that for the 0.03-second exposure time, the letters constructed with 11 lines were as legible as solid (continuous stroke) letters, but the line construction was less legible at 0.003-second exposure. At both exposure times, the 5-line construction was less legible than the solid construction. With 5-line construction and 0.003-second exposure, the wide stroke-width gave better legibility than the narrow width. Confusion between specific letters varied for both line constructions and stroke-widths. The possible effects on legibility of changes in brightness, contrast and letter geometry introduced by the experimental conditions are discussed. It was concluded that the legibility of letters generated by a horizontal linear scan construction is highly dependent upon apparently minor differences in letter geometry." (p. iii)

2610 Botha-1963b

Botha, B. and Shurtleff, D.

Mitre Corp., Bedford, Mass.

STUDIES OF DISPLAY SYMBOL LEGIBILITY. PART II. THE EFFECTS OF THE RATIO OF WIDTHS OF INACTIVE TO ACTIVE ELEMENTS WITHIN A TV SCAN LINE AND THE SCAN PATTERN USED IN SYMBOL CONSTRUCTION

Rept. no. TM-3692, Sep 63, 25 p., 6 refs.

Technical Documentary rept. ESD-TDR-63-440

Contract AF 91(628)-2390

Problem: "(I)nvestigate the effects on legibility of several factors characteristic of linear scan methods (TV raster) of symbol construction and display. These factors were: (1) The ratio of the widths of inactive to active elements within a TV scan line (active elements are those parts of a character that appear on a raster scan line, while inactive elements are those parts of a character that are missing because they are located between scan lines), (2) the scan pattern (the path of the scan element over the symbol) used in symbol construction. . . A second purpose of the present study was to determine whether the method of symbol illumination (reflected light vs. transilluminated light) had an effect on legibility." (p. iii)

Procedure: "Two groups of subjects viewed tachistoscopically transilluminated capital letters at a .03 (second) exposure for each of three different ratios of the widths of inactive to active elements within a TV scan line. Each group viewed letters constructed by a different scan pattern." (p. iii)

Result: "The results showed that both accuracy and speed of response in letter identifications decreased as the ratio of the widths of inactive to active elements increased. The scan pattern used in the construction of letters had a progressively greater effect on response accuracy as the ratio of the widths of inactive to active elements within a TV scan line was increased. The method of symbol illumination had no effect on either response accuracy or speed." (p. iii)

* * *

2149 Bowen-1959

Bowen, Hugh M., Andreassi, John, Truax, Shaffer, and Orlansky, Jesse

Dunlap and Associates, Inc., Stamford, Conn.

OPTIMUM SYMBOLS FOR RADAR DISPLAYS

1 Sep 59, 33 p., 47 refs.

Contract Nonr 2682(00)

AD-227 014

Bowen-1959

Problem: "(D)etermine: (1) sets of geometric symbols which can be discriminated from each other and recognized with high accuracy under a variety of display conditions, especially those involving degradation of the image; and (2) the size and strokewidth to height ratio desirable for symbols to be used on complex displays." (p. 1)

Procedure: "In deciding which shapes to include in the study, first the geometric properties of shapes were considered, second the requirements for writing shapes on radar tubes, and third the requirements for using shapes as symbols to form a symbolic code. . . (p. 2) The primary purpose of (the first) study was to determine the rank discriminability of 20 geometric symbols under various conditions of degradation of noise (none, moderate, and severe), blur (blur and no blur), and distortion (distortion and no distortion). A secondary purpose was to select sets of symbols which, used as a group, would yield minimum confusion between symbols. . . (p. 6) The display conditions produced a light symbol on a dark ground. . . back projected onto the center of a five by five inch square opal glass screen. The size of each symbol when displayed was such that it would just fit in a circle with a 5/8 inch diameter. This gave a symbol height of approximately 0.5 inch for all symbols, and a stroke-width to height ratio of 1 (to) 10. Viewing distance was 50 inches; the brightness of the display was from 4 to 5 foot lamberts, dependent on the noise conditions of the picture. Each slide was projected for 0.5 second . . . (to e)ight subjects (18 to 20 year old male students) . . . (p. 8) The set of ten symbols (derived) was examined further to see whether any of them had any particular weaknesses. . . (p. 16) The second experiment was designed to provide information concerning the optimum size and strokewidth of symbols. . . Four symbols were selected . . .: a circle, a variation of a cross, a square, and a triangle. Three sizes (0.25, 0.375, and 0.50 inches) and three strokewidth to height ratios (1 to 6, 1 to 8, and 1 to 10) were utilized . . . (p. 17) For each condition of symbol construction two displays were made. Each display consisted of 40 symbols placed on a 12 (inch) diameter display, and distributed evenly over the display. Each of the four symbols was shown . . . up to thirteen times . . . There were 8 male observers of 17 or 18 years of age whose vision was tested as normal." (p. 18)

Result: "Various combinations of symbols that will not be confused with each other are ." . . (p. 1) as follows: (symbol numbers refer to the 20-figure matrix shown in appendix)

| number of symbols in set | recommended symbols (for additional symbols use: 11, but not with 3; 12, but not with 5 or 7; and 13, but not with 8) |
|---|---|
| 2 | 1 and 2; or 1 and 3; or 2 and 3; or 7 and 14; or 5 and 7; or 5 and 14 |
| 3 | 1, 2, and 3; or 5, 7, and 14 |
| 4 | 1, 2, 3, and 4; or 5, 6, 7, and 14 |
| 5 | 1, 2, 3, 4, and 5; or 4, 5, 6, 7, and 14 |
| 6 | 1, 2, 3, 4, 5, and 6 |
| 7 | 1, 2, 3, 4, 5, 6, and 7 |
| 8 | 1, 2, 3, 4, 5, 6, 7, and 8 |
| 9 | 1, 2, 3, 4, 5, 6, 7, 8, and 9 |
| 10 | 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 |

(above from p. 15)

"Symbols should be about 1/2 inch high and have a strokewidth 1/8 to 1/10 of their height. If small symbols must be used, the strokewidth to height ratio must be 1 (to) 10 or less, but not smaller than 0.02 inch. Where display conditions are poor, symbols should be increased in size. . . Selection and number of symbols should conform to the following rules:

1. "The choice of symbols should permit the observer to identify the class to which a symbol belongs without necessarily identifying its group or subgroups;
2. "Care should be taken to select distinctive shapes for infrequently occurring symbols since infrequent symbols are likely to be recognized slowly and with greater error. Symbols representing very important items must be chosen from the set of 'best' symbols, particularly when they occur infrequently;
3. "Primary symbols should be large and enclose a space;
4. "No auxiliary symbol should cross, distort, interfere with or in any way obscure the primary symbol(s);
5. "Symbol complexes should not normally exceed two geometric symbols, a location dot, and a speed and direction vector line; and
6. "A symbol code should comply with the conventional and stereotyped meanings normally associated with such symbols." (p. 1)

* * *

3268 Brainard-1961

Brainard, Robert W., Campbell, Richard J. and
Elkin, Edwin H.
Laboratory of Aviation Psychology, Ohio State U., Columbus
DESIGN AND INTERPRETABILITY OF ROAD SIGNS
Journal of Applied Psychology, 45:2 (April 1961) 130-136

Problem: "(I)nvestigate the interpretability of selected European road signs, to determine if stereotypes exis(t) for signs, to compare the general characteristics of the European signs with the characteristics embodied in the stereotypes, and to determine if stereotype-based signs enhanc(e) interpretability." (p. 135)

Procedure: In phase I, 29 Ohio State University subjects viewed 30, 12- by 12-inch signs mounted on display cards for 30 seconds each. Their task was to write "the meaning which they thought a sign conveyed . . . ." (p. 135) In phase II, 33 different subjects viewed the same signs under the same conditions in choosing from a list of possible meanings the one meaning which best matched the particular sign being shown. . . (p. 135) The score used was the percentage of correct matchings. . . In (p)hase III, the same (subjects) . . . (as) in (p)hase II were told the meanings of the signs. Then the signs were presented again and (the subjects) wrote the meaning which they thought the sign conveyed." (p. 130) In phase IV, sixteen "sign meanings were read to (31 new subjects), and they designed (with a 2-minute time limit each) signs which would convey these meanings." (p. 135) In phase V, "10 sign drawings were constructed from the drawings of (p)hase IV.

Twenty-nine new (subjects) .". . (p. 131) viewed and responded to these under the same conditions as in phase I.

Result: "The results of the study can be summarized as follows:

1. "Interpretability of the European signs was partly a function of the method by which interpretability was examined. The mean interpretability score from (p)hase I was considerably lower than for (p)hase II, although the correlation between the two methods was significant.
2. "The European signs were moderately well interpreted on first presentation; after one exposure to the correct meaning, interpretability approached 100 (percent).
3. "The easily interpreted European signs were generally pictorial representations of the sign meanings or were counterparts of American road signs. The signs which were difficult to interpret generally used abstract, unfamiliar symbols or included ambiguous cues.
4. "Stereotypes for some road signs exist. The general characteristics found in the stereotypes were the same as those in the easily interpreted European signs.
5. "Interpretability is enhanced if signs are stereotype-based. However, signs based on stereotypes of only moderate strength (30-40 percent) will not always be highly interpretable.
6. "A small number of the European road signs (not specifically delineated) could be . . . used in the United States, without necessitating prior instruction as to their meaning. The majority . . . however, could not be used without a minimal degree of familiarization." (p. 136)

* * *

3356 Breland-1944

Breland, Keller and Breland, Marian K.
Minnesota U., Minneapolis
LEGIBILITY OF NEWSPAPER HEADLINES PRINTED
IN CAPITALS AND IN LOWER CASE
Journal of Applied Psychology, 28:2
(April 1944) 117-120, 3 refs.

Problem: "(C)ompare the legibility of newspaper headlines printed completely in capitals with the legibility of those printed in capitals and in lower case where the initial letters of the important words only are capitalized. . . For purposes of the present study, legibility is defined in terms of the number of words read during a brief exposure time and correctly reported by the subject immediately after the exposure." (p. 117)

Procedure: "The material used . . . consisted of 120 (single-column,) five-word newspaper headlines. . . taken from . . . the New York Times. . .(,) printed in 24-(point)

CHELTENHAM bold-face, extra-condensed type in two lines on newsprint. . . (and) pasted on 5-1/2(-inch by) 3-3/4(-inch) tachistoscope cards which had first been covered with newsprint paper stock. . . Each of the . . . headlines was printed . . . once in capitals and once in lower case. . . Twenty-two senior and graduate (university) students . . . (viewed the stimuli in) the Dodge Mirror Tachistoscope. . . for 50 milliseconds . . . (each), and the subject then wrote on (the) blank (provided) as many words as he could. . . (p. 118) The responses were scored by recording the number of words correctly reported for each headline, regardless of the order in which they were reported. . . (M)isspelled words were counted as wrong." (p. 119)

Result: "Th(e) results indicate that for the length and type face here considered, headlines printed in lower case are considerably more legible (statistically highly significant) than those printed entirely in capitals, when legibility is defined as the number of words which can be correctly reported after a 'glance' at the headline. . . (p. 119) (Specifically), there (was) 18.9 per cent loss in reading headlines set in all capitals in comparison with lower case. . . Furthermore, the percentage difference is larger than that previously obtained in the reading test comparison by Tinker and Paterson. . . In view of these results, it seems incontrovertible that a real difference exists in favor of single-column headlines printed in lower case versus all capitals. Moreover, it does not seem necessary to compare 24 (point) capitals with 36 or 48 (point) lower case, since 24 (point) lower case headlines are obviously markedly superior in legibility to headlines in the same size capitals." (p. 120)

* * *

3296 Bridgman-1956

Bridgman, C. S., and Wade, E. A.
Wisconsin U., Madison
OPTIMUM LETTER SIZE FOR A GIVEN DISPLAY AREA
Journal of Applied Psychology, 40:6 (December 1956) 378-380, 5 refs.

Problem: "Given a certain display space, limited by a high-contrast border, what is the maximally visible size of (an) inscribed . . . single line of BLOCK capital letters, (using) a visual acuity criterion of visibility?" (p. 378)

Procedure: Forty male and female subjects (psychology students each having at least 20/20 binocular visual acuity) viewed five, five-letter lines of BLOCK, upper case, alphabetic characters projected onto (1) "an aluminized projection screen," (p. 378) and (2) "a flat black mat surface." (p. 378) The experiment was of a minimum recognition size "threshold" design. The two background surfaces provided luminance levels of 8.45 and 0.084 millilamberts, respectively. Ratios of letter size to vertical dimension of the background utilized were 1 to 1, 1 to 1.4, and 1 to 5.5. Using a variable magnification projector, "the relations stated above were maintained as letter size was varied to

determine thresholds. . . Projection and observation distance were both 20 feet." (p. 378)

Result: "Providing a field equal to the stroke width of the letters gave improvement in mean acuity thresholds of nearly 11 (percent) over those obtained with no field, and the wider field (2.25 times the letter size) gave improvements of 18 to 20 (percent). These proportional increases were approximately equal at both luminance levels. . . When the data are examined in terms of the over-all size of field required to provide threshold letters, however, it is found that the decrease in letter size is not enough to compensate for the additional space taken up by the field. It is concluded that, when space limitations are a consideration, letters should be made as large as possible up to the point of very nearly filling the available space (margin less than the stroke width of the letters), in order to permit discrimination at a maximum distance." (p. 380)

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3332 Brown-1949a

Brown, Fred R., and Lowery, Edward A.
Aeronautical Medical Equipment Lab.,
Naval Air Material Center, Philadelphia, Pa.
A STUDY OF THE REQUIREMENTS FOR LETTERS, NUMBERS AND MARKINGS TO BE USED ON TRANSILLUMINATED AIRCRAFT CONTROL PANELS. PART 1. THE EFFECTS OF STROKE WIDTH UPON THE LEGIBILITY OF CAPITAL LETTERS
Rept. TED no. NAM EL-609, Part I, 26 Sep 49, 19 p., 10 refs.
ATI-205 706

Problem: Determine the effect of varying stroke-width, brightness of red trans-illumination, level of floodlighting simulating daylight, and time of exposure upon the legibility of capital letters of fixed height and width "to be used on trans-illuminated control panels in the cockpits of military aircraft." (p. 2)

Procedure: A total of 89 subjects, in three test series, viewed (at 28 inches) Navy GROW CHART capital letters, light-on-dark, in three-letter groups in a tachistoscope. Letter heights were all 0.156 (5/32) inches (and width equals height in these letters). Stroke-width was varied as follows:

| stroke-width (inches) | stroke-width to height ratio |
|---|---|
| 0.0312 | 1 to 5 |
| 0.0260 | 1 to 6 |
| 0.0206 | 1 to 7.5 |
| 0.0156 | 1 to 10 |
| 0.0104 | 1 to 15 |

The level of floodlighting was varied between none, 40, and 80 foot-candles. The brightnesses of trans-illumination were 0.35, 0.85, 1.75, 2.80, and 3.60 millilamberts. Exposure times were 1/5th and 1/25th of a second.

Result: The following results were obtained for the conditions indicated:

| exposure time | trans-illumination brightnesses | background lighting |
|---|---|---|
| 1/25 sec. | below 3.60 millilamberts | dark |
| (legibility improved non-linearly with increase in stroke-width) | | |
| 1/25 sec. | 3.60 millilamberts | dark |
| (legibility improved to a maximum at a stroke-width of 0.0260 inches and then decreased for the larger width) | | |
| 1/5 sec. | low and middle | dark |
| (legibility improved over 1/25 second, but only at the lowest brightness did legibility improve with increasing stroke up to the highest width---in the middle range of brightnesses, no great improvement in legibility is noted when stroke is increased up to the largest width, at which point legibility appears to drop) | | |
| 1/5 sec. | 3.60 millilamberts | dark |
| (a definite indication was obtained of optimal legibility with the smallest stroke-width---at the same time, the largest stroke-width yielded definitely decreased legibility over the narrower stroke-widths) | | |
| unspecified | unspecified | 40 and 80 foot-candles |
| (legibility improved markedly when the stroke-width was increased from 1/15 to 1/10 of letter height---however, there was only a small increase for widths greater than 1/10, and improvement was very small for widths greater than 2/15 the letter height) | | |

Thus, "(f)or use on the trans-illuminated plastic plates for the control consoles of aircraft cockpits, where brightness levels will usually be low to preserve dark adaptation, but when occassionally higher brightnesses might be used, a ratio of stroke width to letter height of 1 (to) 6 appears optimal. This same ratio shows a high legibility for daylight reading as well. . . AIRPORT SEMI-BOLD, FUTURA DEMI-BOLD, and VOGUE MEDIUM appear to have the optimal stroke width/letter height for this use. . . It is also recommended that, to preserve dark adaptation, trans-illumination brightnesses on these panels be kept as low as will permit adequate legibility of the markings." (p. 18)

* * *

3333 Brown-1949b

Brown, Fred R.

Aeronautical Medical Equipment Lab.,

Naval Air Material Center, Philadelphia, Pa.

A STUDY OF THE LEGIBILITY OF TRANS-ILLUMINATED MARKINGS IN AIRCRAFT COCKPITS

Brown-1949b

Rept. TED no. NAM EL 600, Part 2, 25 Feb 49, 33p., 11 refs.
ATI-93 994

Problem: "(D)etermine the principles governing the legibility of red trans-illuminated GROW CHART letters under conditions simulating those encountered in reading markings on new type aircraft cockpit console panels." (p. 2)

Procedure: "Seventy-five subjects read the (all capital, light on dark) letters from a distance of 28 (inches) in the dark . . . . The variables in the tests were letter size (0.04, 0.06, 0.08, and 0.12 inches high), brightness of trans-illumination (24, 40, 62, and 80 microlamberts) and level of background floodlighting (11, 33, and 110 x $10^{-3}$ foot-candles of red illumination on the cards). . . (p. 2) Among the possible problems with this type of illumination are .". . (p. 5) the following:

1. "Do trans-illuminated markings offer a different legibility problem than do ordinary low-reflectance markings on a high-reflectance background or the reverse combination using reflected light?
2. "In what way does the color of the illumination affect legibility of trans-illuminated markings?
3. "In what way does the brightness of . . . trans-illuminated markings affect (their) legibility . . . ?
4. "What effect have size and combinations of sizes of trans-illuminated markings on legibility?
5. "What effect does the amount of background lighting have on the legibility of trans-illuminated markings?
6. "Is additional floodlighting needed for orientation with trans-illuminated consoles?
7. "Do any illusory effects result from reading trans-illuminated markings? Are these effects changed with addition of background lighting?
8. "What forms of letters and markings are most legible when trans-illuminated?
9. "Are there any other subjective effective from combinations of background floodlighting and trans-illumination such as reduction in haze or after-image occurrence?" (p. 5)

Result: The following conclusions and recommendations were given:

1. "The legibility of red trans-illuminated letters increase(d) with the increasing brightnesses of trans-illumination . . . and with the increasing letter sizes used. However, there (were) certain critical size and brightness combinations for which small changes in brightness or size produce(d) large changes in legibility. With uneven light distribution and with variable size of letters on individual console panels, these critical size-brightness combinations . . . occur(red). Thus with brightness adjusted for one of the larger or better illuminated markings, a smaller or more poorly illuminated marking might be at a critically low level of legibility."

(p. 32) Therefore, it was recommended that "(l)ettering on trans-illuminated consoles should be of uniform size and brightness. If size differences are needed for emphasis of some few elements, the number of different sizes should be kept to a minimum. . .

2. "When a low level of red background floodlighting (up to about $50 \times 10^{-3}$ foot candles, was) added to a trans-illuminated panel with background reflectance of about 5 (percent), no marked change in legibility occur(red), if the legibility lever (were) already very low or very high. But for those markings which (were) in the neighborhood of 50 (percent) legibility, a low level of floodlighting tend(ed) to decrease legibility significantly. A higher level of floodlighting (above $50 \times 10^{-3}$ foot candles) increase(d) legibility in all cases." (p. 32) These results lended support to a recommendation that there is a "need for uniform console floodlighting so that the effects on legibility will be the same on all the console panels in a cockpit." (p. 32)

In general, it is concluded "that uniformity in size and brightness of markings on console panels would insure that the legibility of all markings (would) vary uniformly as the brightness (was) changed. . . (and) that uniformity of floodlighting on . . . panels would result in equal changes in legibility for all . . . trans-illuminated markings as the floodlighting level (was) changed." (p. 2)

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2612 Brown-1951

Brown, Fred R., Lowery, Edward A. and
Willis, Marion P.
Aeronautical Medical Equipment Lab.,
Naval Air Material Center, Philadelphia, Pa.
A STUDY OF THE REQUIREMENTS FOR LETTERS, NUMBERS, AND MARKINGS TO BE USED ON TRANS-ILLUMINATED AIRCRAFT CONTROL PANELS. PART 3. THE EFFECT OF STROKE WIDTH AND FORM UPON THE LEGIBILITY OF NUMERALS
Rept. TED no. NAM EL-609, Part 3, 24 May 51, 32p., 19 refs.
ATI-107 638

Problem: Determine the effect of varying numeral form, stroke-width, and general illumination on the legibility of numerals. From the results, design a set of "optimal" numerals.

Procedure: BERGER and AND 10400 numerals, in stroke-width to height (.156 inches) ratios of 1 to 15, 1 to 8.6, 1 to 8, 1 to 7, and 1 to 6, were viewed (in light on dark), under

both "floodlighting simulating daylight (both 40 and 80 foot-candles) and the red trans-illumination used in night operation.". . (p. 4) by a total of 60 subjects at tachistoscopic exposures of 0.007, 0.040, and 0.200 seconds. As a point of interest, there are "inherent factors which influence the selection of the markings to be used on . . . aircraft trans-illuminated cockpit console . . . panels. These factors may be . . . as follows:

1. "The markings have a contrast relationship the reverse of that normally encountered; that is, the markings are brighter than their surroundings. By day they are white against a black background; by night they are self-luminous red with the background either fully blacked out or with a variably low level of red floodlighting.
2. "The console panels are arranged in the cockpit at varying distances from the pilot's eyes. There may be a range of from 15 . . . to 35 (inches) in the reading distances which will be employed. Frequently, the pilot's head position cannot be altered enough to change significantly the eye to panel distances . . . .
3. "For reasons of design economy and simplification of the visual task, it is desirable that the markings have the same configuration for day and night viewing.
4. "In designing markings, consideration should be given to the range of brightnesses which actually will be employed in night operations and the range of illumination levels which will be found during day use. Where optimal design characteristics may vary with the changing illumination situation, the recommended design should be based on a consideration of the relative importance and critical nature of each of the reading situations.
5. "The size of markings is somewhat limited by the overall requirement that the luminous flux be reduced to a minimum in the cockpit. In addition, the size of markings is limited by the need for kee ping nearby markings sufficiently spaced for clarity.
6. "The size of letters, numerals and other markings should be comparable. Otherwise, as in a panel employing a variety of sizes for markings, the larger markings will appear subjectively brighter and will localize attention. In addition, at the low brightness levels which may be employed, the smaller markings might be at a critical level of legibility." (p. 5)

Result: "The results (of the experiment) indicate(d) a general preference for the BERGER form. Especially noteworthy (was) the much higher legibility of the BERGER '4'. The remainder . . . (had) only slight differences in legibility . . . , except the '9' which under daylight (was) distinctly better in the AN form. . . Of the individual numerals, the '7', '1' and BERGER '4' (were) the most recognizable. The least recognizable (were) the '8', '0' and '3'. . . The stroke-width data indicate(d) that a stroke-width to height ratio of 1 (to) 8 is optimal when all the conditions of use (were) considered, especially the low trans-illumination levels recommended for use in aircraft cockpits to facilitate dark adaptation. Under trans-illumination, numerals with stroke-width to height ratios of 1 (to) 7 and 1 (to) 8.6 (were) nearly as legible as those with a ratio of 1 (to) 8." (p. 4) From these results,

"(a) series of digits has been designed incorporating the characteristics of the numerals tested which appear(ed) to improve digit legibility." (p. 4)

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2611

Brown, Fred R.
Aeronautical Medical Equipment Lab.,
Naval Air Material Center, Philadelphia, Pa.
A STUDY OF THE REQUIREMENTS FOR LETTERS, NUMBERS, AND MARKINGS TO BE USED ON TRANS-ILLUMINATED AIRCRAFT CONTROL PANELS. PART 4. LEGIBILITY OF UNIFORM STROKE CAPITAL LETTERS AS DETERMINED BY SIZE AND HEIGHT TO WIDTH RATIO AND AS COMPARED TO GARAMOND BOLD
Rept. TED no. NAM EL-609, Part 4, 10 Mar 53, 20p., 5 refs.
AD-10 211

Problem: "(D)etermine the effect of variations in size and in height-to-width ratio upon the legibility of capital BLOCK letters as they would be used in aircraft cockpit plastic lighting plates." (p. 2)

Procedure: A total of 120 male subjects viewed sans-serif, uniform stroke-width, BLOCK capital letters and also viewed GARAMOND BOLD capital letters, both in light on dark and in groups of three letters, at tachistoscopic exposures of 1/5 and 1/25 second. Other variables were as follows: letter height = 0.12, 0.13, 0.14, 0.156, 0.17, and 0.18 inches; height-to-width ratio = 1.00, 1.17, 1.43, and 1.81 to 1 (for GARAMOND BOLD, the height-to-width ratio was standard, and the letters varied individually from 1 to 0.67 to 1 to 1.33); red trans-illumination = 0.30, 0.80, 1.60, 2.60, and 3.30 foot-lamberts; and background illumination = dark, and 40 and 80 foot-candles.

Result: "The experimental studies . . . (led) to the following conclusions:

1. "Letter legibility improve(d) as letter width (was) increased to a width equal to the height. Marked loss in legibility (was) found when letter width (was) narrower than 2/3 the height. (p. 18)
2. "GARAMOND BOLD, a commercial type characterized by variable strokes, serifs, and variable widths, was not shown to have legibility advantages over uniform stroke letters in this application, especially in daylight.
3. "While there (was) legibility improvement with every size increment tested, the data indicate(d) especially marked legibility improvements up to the size of 0.140 (inches). This size, especially in daylight and with low transillumination luminance levels, (was) selected for the general run of lettering on plastic plates." (p. 19)

Brown-1953

Final "recommendations for the form and size for letters to be used on plastic lighting plates . . . derived from (this) and previous studies . . . and from recognized good practice. . . are as follows:

1. "Uniform stroke-width letters should be used in which the stroke-width is one sixth the height. The stroke-ends should be squared with no serifs. The width of the letters shall be equal to the height, where space allows. If necessary, narrower letters may be used, but not narrower than 2/3 the height. Exceptions where 1 (to) 1 letters are used are: the 'I', one stroke wide; the 'J' and 'L', 3/4 the height in width; the 'W' one stroke-width wider than the height.
2. "Two sizes of letters appear to satisfy the concurrent desirability of uniform size but with occasional larger letters for special emphasis. These sizes are: 9/64 (inches) for the bulk of the letters and 11/64 (inches) for the emphasized letters.
3. "The BLOCK forms for the recommended letters are shown . . . . This form is generally called GOTHIC. Since typographic catalogues are variable as to the names given to type forms which approach the design (shown) . . . , no fixed commercial designation can be referenced. However, these are suggested as commercial designs to be considered: AIRPORT SEMI-BOLD, FUTURA DEMI-BOLD, VOGUE MEDIUM and LINING GOTHIC NO. 66. For engraving processes GORTON EXTENDED is a similar form. However, in an engraving technique stroke width is dependent upon engraving tool size and stroke ends are necessarily rounded." (p. 19)

* * *

2619 BurPR-nd(a)

Bureau of Public Roads, Washington, D. C.
SPACING, IN INCHES, FOR 10-, 12-, and
18-INCH (LOOP HEIGHT) LOWER CASE LETTERS WITH
INITIAL CAPITALS OF A HEIGHT 1.33 TIMES THE
LOWER CASE LOOP HEIGHT
Table, undated

Abstract: This is a chart, showing the spacing, in inches, for 10-, 12-, 15-, and 18-inch (loop height) lower case letters with initial capitals of a height 1.33 times the lower case loop height. The initial or preceding letters are grouped as follows: A W X, B, C E G, D O Q R, F, H I M N, J U, K L, P, S, T, V, Y, Z, a d g h i j l m n q u, b f k o p s, c e, r, t z, v y, w, and x. Following letters are grouped as follows: a c d e g o q, b h i k l m n p r u, f w, j, s t, v y, x, and z.

* * *

2617 BurPR-1958

Bureau of Public Roads, Washington, D. C.
STANDARD LOWER-CASE ALPHABETS FOR HIGHWAY SIGNS
March 1958 (Reprint 1962), lv.

Text: "Approved standards for directional signs on the National System of Interstate and Defense Highways prescribe that destination names shall be in lower-case letters, with initial capitals. This lower-case alphabet has accordingly been prepared by the U.S. Bureau of Public Roads for the American Association of State Highway Officials.

"The alphabet is basically that developed by the California Division of Highways after extensive research. It has been tested in service in that State and, with some modifications, on a few expressways elsewhere.

"The standards for signs on the interstate highway system prescribe that initial capital letters shall be one-third higher than the 'loops' of the lower-case letters used with them. Esthetically and practically this sets a limit to the height of the 'ascenders' in the lower-case letters. The present alphabet accordingly has been designed so that all projections above the nominal or loop height of the lower-case letters are just one-third that loop height. The same limitation does not apply to extensions below the 'base' line, hence the 'g' and the 'j' are made to drop downward one-half the loop height, and the 'p,' 'q,' and 'y' three-eights the loop height.

"The extended, straight vertical strokes are cut off at an angle of 20 degrees from the horizontal.
"For proportional enlargement to any desired size the letters have been laid out on a grid of one-half-inch squares, so that they can easily be transferred, square by square, to a grid of any other size. They may also, of course, be enlarged photographically.

"In accordance with usual practice, all curves or projecting angles have been extended slightly above or below the nominal vertical limits of the loop or the over-all letter height.

"It should be noted that the heavy black outlines of the letters lie wholly outside the actual area of the letters.

"It is recommended that the initial capitals and the numerals used with these lower-case letters be Series E of the Standard Alphabets for Highway Signs, approved 1945, but with the stroke-width widened to approximately one-fifth of the letter or numeral height.

"Modification of these letters is permissible within reasonable limits, particularly where required by manufacturing processes or by the type of reflectorization that will be used."

* * *

Bur PR - 1961

2618 Bur PR - 1961

Bureau of Public Roads, Washington, D. C.

STANDARD ALPHABETS FOR HIGHWAY SIGNS

1961 (Reprint), lv.

Text: "These Standard Alphabets for Highway Signs were designed by the U.S. Bureau of Public Roads at the request of the Joint Committee on Uniform Traffic Control Devices, approved by that committee, and first published in 1945. The 'rounded' style was created to replace an earlier more angular design, for better legibility and a more pleasing appearance.

"Most highway departments and sign manufacturers will find it desirable to make up a set of templates of light material to simplify the laying out of signs. The letters and numerals may be reproduced in any required size by following the table of dimensions carried on each sheet of the drawings (or by adjusting dimensions proportionally for sizes not shown), or by a photographic enlargement or reduction of drawings of any size. It is not recommended, however, that photographic enlargements be made from the small printed drawings, which will be found to vary slightly in dimensional accuracy.

"To facilitate the laying out of different sizes of letters and numerals, the detailed dimensions are shown only in a letter code referring to the tabulation at the bottom of each sheet. Tangents, major arcs, and certain indicated control points are laid down first, followed by the connecting arcs of shorter radius. Two circumstances must be noted:

1. "Under certain conditions the radii of connecting arcs cannot be given precisely. In these cases there is only one possible arc that can fit accurately to all controlling points. The dimension given on the drawing is a close approximation, but the draftsman may have to make a slight adjustment to achieve a perfect fit. This applies especially to the large letters, since the dimensions on the tables were generally derived from measurements on smaller drawings.
2. "For similar reasons, it is not practical to show the exact centers of all arcs. Centers are invariably indicated for the controlling arcs. For others the draftsman must set his compasses and find the center by experiment.

"The stroke-width of the letters and numerals is uniform throughout any size and series of alphabet, except where otherwise definitely indicated.

"All characters having an arc at top or bottom are extended slightly above or below the line of the other letters. This is in accord with accepted practice for rounded letters.

"If the design of any particular letter or numeral in a given size is incompatible with any manufacturing process, necessary modifications may be made within reasonable limits. For example, the height or length of a horizontal member may have to be adjusted slightly to permit a satisfactory arrangement of reflector buttons, or to provide necessary

clearance for embossing dies."

* * *

2615 Burt-1959

Burt, Cyril L.

London U. (Gt. Brit.)

A PSYCHOLOGICAL STUDY OF TYPOGRAPHY

Cambridge, University Press, 1959, 68 p.

Problem: Determine the effect of style, boldness, size, leading, line width, margin width and interactions between these on the readability and esthetic quality of type faces currently used in children's books and scientific journals, with a particular view toward improving the readability of the British Journal of Statistical Psychology.

Procedure: The following outline of contents, including the experimental material, is indicative of the book's scope and wealth of information on the aspects of typography pertinent to readability:

Preface.

Introduction by Stanley Morison.

I. The investigation of typographical problems; printing as a medium of communication.

II. Legibility (readability); (including) the legibility (readability) of children's reading books.

- A. Methods.
- B. Influence of various factors.
  1. Type faces (styles).
  2. Boldness.
  3. Size (in points).
  4. Leading (between lines).
  5. Measure (line width).
  6. Margins.
  7. The interaction of these factors.
- C. Practical corollaries.
- D. Introspections.

III. Aesthetic preferences and the classification of type faces; the study of preferences.

- A. Methods.
  1. Correlations between persons; introspections.
     - a. Subjective.
       - i. Associative.
       - ii. Emotional.
       - iii. Anthropomorphic.

b. Objective.
  i. Intuitive.
  ii. Rationalizations.
2. Correlations between type faces.

B. The preferences and their causes; general order; orders for main group and subgroups; the bipolar factor; legibility and preferences; and supplementary factors.

C. Implications for psychology and education.

IV. Summary and conclusions.

Appendix - The characteristics of the commoner type faces: readers' comments and historical notes; (including) modern developments in printing, origins.

A. Old faces.
1. Continental.
  a. Italian.
    i. BEMBO.
    ii. VERONESE.
    iii. CENTAUR.
  b. French.
    i. GARAMOND.
    ii. GRANJON.
    iii. FOURNIER.
    iv. PLANTIN.
    v. EHRHARDT.
2. British.
  a. CASLON.
  b. BASKERVILLE.
  c. OLD STYLE.
  d. IMPRINT.
  e. TIMES NEW ROMAN.
  f. PERPETUA.

B. Modern faces.
1. Continental.
  a. BODONI.
  b. DIDOT.
  c. WALBAUM.
2. British.
  a. BELL.
  b. SCOTCH ROMAN.
  c. MODERN SERIES 7.

C. Italic.

D. Mathematical publications.

Specimens of type faces (of those referred to in the appendix, sections A. and B., above).
Glossary (including a pictorial description of the parts of a type slug).
References.
Indexes.

A. Subjects and persons.
B. Letters of the alphabet.
C. Type faces.

In investigating "(a) the legibility and (b) the aesthetic merits of (type faces) in more frequent use," (p. 1) the following was done. . . "Using tests of speed and comprehension (supplemented by observations of eye movements, blinking, and other symptoms of eye-strain), we have studied the influence of (the parameters noted above in II. B.) on legibility, both with children and adults. . . Factorial methods, supplemented by an analysis of introspections, appear to yield a classification of both readers and type faces based on aesthetic preference; and the data incidentally obtained throw considerable light on the reasons for such preferences." (p. 1)

Result: "It should again be emphasized that our conclusions are themselves merely tentative . . . .": (p. 17)

1. A 5-inch line width (adopted for the British Journal of Statistical Psychology) "seems satisfactory for academic readers." (p. 17)
2. A line width of 4-5/8 inches (adopted for the British Journal of Educational Psychology) "is well suited for a journal of a slightly more popular kind." (p. 17)
3. "(S)hort lines (2-2/3 inches) recently introduced by the British Journal of Medical Psychology, . . . two columns to a page, are more likely to diminish speed of reading . . . ." (p. 17) This line width could be particularly bad in a book or periodical dealing with advanced mathematics.
4. "For mathematical work the committee of the Royal Society selected . . . IMPRINT, TIMES NEW ROMAN, and MODERN 7." (p. 17)
5. "For books . . . 11-point IMPRINT (large face) on a 12-point body set in . . . 23 ems (3.83 inches)" (p. 17) line width, "or 25-28 ems if there are numerous equations." (p. 17)
6. "For ordinary periodicals . . ., provided no formulae in italic are required, the best type . . . appears to be 10-point TIMES ROMAN with long descenders and with 1-point leading (2-point if the . . . version, with short descenders, is used)." (p. 17)
7. "For subsidiary matter (in periodicals), 9-point with -1point leading, . . . might be (used)." (p. 17) However, "no serious difficulty seemed to be experienced with short footnotes of 8-point, even when set solid . . . ." (p. 17) It has been suggested that "8-point footnotes . . . might be divided into two columns." (p. 18)
8. "For books, . . . a slightly larger size will often be preferable (for subsidiary matter), e.g. 11-point TIMES ROMAN or 12-point BASKERVILLE or BEMBO." (p. 18)

Burt-1959

"Mrs Beatrice Warde has rightly observed, 'What the book critic calls readability is not a synonym for what the optician calls legibility.'" (p. 18) It was also observed, on the basis of comments elicited from the subjects, "that almost everyone reads most easily matter set up in the style and size to which he has become habituated." (p. 18) In esthetic preference, the following table shows the results of subjective inquiry:

| Type face name | Roman faces Literary group | Roman faces Scientific group | Roman faces Total | Italic faces Literary group | Italic faces Scientific group | Italic faces Total | Combined total |
|---|---|---|---|---|---|---|---|
| IMPRINT | 1 | 6 | 1 | 3 | 5 | 3 | 1 |
| TIMES NEW ROMAN | 7 | 2 | 2 | 8 | 7 | 6 | 2 |
| BEMBO | 3 | 9 | 3 | 2 | 10 | 4 | 4 |
| PLANTIN | 2 | 13 | 4 | 7 | 6 | 5 | 5 |
| BASKERVILLE | 11 | 5 | 5 | 11 | 4 | 9 | 7 |
| MODERN | 15 | 1 | 6 | 4 | 1 | 1 | 3 |
| CASLON | 6 | 12 | 7 | 6 | 8 | 8 | 8 |
| BELL | 13 | 4 | 8 | 10 | 3 | 7 | 9 |
| SCOTCH ROMAN | 16 | 3 | 9 | 5 | 2 | 2 | 6 |
| GRANJON | 8 | 14 | 10 | 13 | 16 | 14 | 11 |
| CENTAUR | 4 | 18 | 11 | 1 | 13 | 10 | 10 |
| VERONESE | 5 | 19 | 12 | 12 | 12 | 13 | 13 |
| GARAMOND | 9 | 17 | 13 | 9 | 11 | 11 | 12 |
| FOURNIER | 10 | 16 | 14 | 15 | 15 | 15 | 15 |
| OLD STYLE | 14 | 11 | 15 | 16 | 9 | 12 | 14 |
| EHRHARDT | 12 | 15 | 16 | 14 | 19 | 16 | 16 |
| DIDOT | 17 | 8 | 17 | 17 | 18 | 19 | 17 |
| WALBAUM | 18 | 7 | 18 | 18 | 17 | 18 | 18 |
| BODONI | 19 | 10 | 19 | 19 | 14 | 17 | 19 |

(above from p. 27)

The following general conclusions were drawn:

1. "(T)he different characteristics . . . necessarily condition and interact with each other.
2. "On the whole, OLD STYLE ANTIQUE appeared most appropriate for children under 12, and IMPRINT, PLANTIN, or TIMES NEW ROMAN for those over 12.
3. "With adult readers enjoying normal vision wide variations in design, size, or measure seemed permissible without greatly affecting efficiency of reading.
4. "Type having an x-height (the relative height of a lower-case letter, measured from the base line to the top of the lower-case x) of about 0.060 (inches) (e.g. 10-point TIMES NEW ROMAN or 11-point IMPRINT or MODERN 7), with 2-point leading (or 1-point with type small on its body) and a measure of 20-23 ems, appeared to be most satisfactory for general purposes.
5. "Slightly wider measures and somewhat narrower margins seemed preferable for technical publications; slightly narrower measures and larger sizes of type for literary works." (p. 30)

* * *

2621 Carmichael-1947

Carmichael, L. and Dearborn, W. F.
READING AND VISUAL FATIGUE
Boston, Houghton Mifflin Co., 1947

Problem: Study visual fatigue "as a description of what the organism does" (p. 3) and to "characteriz(e) certain changes in organisms or parts of organisms following activity. In this (the descriptive) sense, the word fatigue may be applied to . . . patterns of psychological, physiological, biochemical, or . . . physical alterations . . . ." (p. 3) It may also "apply to . . . the following phonemena: subjective feeling-tone; alteration of behavior, motivation, or physiological activity; biochemical change in active tissues; . . . (and) molecular or . . . physical changes in a living tissue . . . ." (p. 3) However, it is not meant here to include emotional disorder or "personality alteration."

Procedure: The book's table of contents shows the following primary chapter headings:

1. What Is Visual Fatigue?
2. The Visual Task of Reading.
3. Reading and Fatigue.
4. Reading the Printed Page.
5. The Problem of Illumination.
6. The Recording of Eye Movements.
7. The Methodology of the Present Experiments.
8. The Electro-Oculogram.
9. Books and Reading Groups.
10. Changes in Comprehension and Related Processes.
11. Discussion and Interpretation of the Results of These Experiments.
12. Summary and Conclusions.

"These experiments (optimal type of format, lighting, and other conditions) were undertaken in order to study the effects of prolonged reading of books or microfilm in causing what is popularly termed 'visual fatigue.' Stated in other words, the problem to be investigated is the determination of how long a normal human subject can continue to read (with motivation) before there are significant changes in his reading behavior." (p. 206)

Result: The following conclusions were drawn:

1. "(A) book can be read by a normal subject continuously for six hours without undue signs of fatigue . . . ." (p. 358)
2. "(M)icrofilm reading can be carried on for six hours without unduly fatiguing the normal subject . . . ." (p. 358) However, one group of subjects (who exhibited the lowest general academic aptitude as measured by "intelligence tests") "read the microfilm reproduction . . . less well than . . . the regularly printed." (p. 359)
3. There seemed to be no distinction between fatiguing of the two educational ages of subjects (high school and college).

4. "No single factor that we have isolated as delimiting the experimental situation in the present investigations produced special differences in ability to read for six hours." (p. 359) Nor were there any consistent "significant differences in total performance . . . when any single factor . . . was varied . . . in relation to other factors." (p. 360)
5. "The so-called intrinsic interest of the material . . . was not found to be associated with significant differences in fatigue or in the capacity to read with understanding for six hours." (p. 360)
6. "(R)eading for six hours in a relatively fixed posture does in some way (undesirably) affect the total organism." (p. 360)
7. "(O)ne seems forced to assume that the total visual mechanism . . . is able to function approximately as effectively at the end of a long period of continuous activity as at the onset . . . ." However, "eventually a combination of 'local' and 'general' fatigue would . . . produce a change . . . ." Yet, "sleep deprivation . . . might first show . . . ." (p. 361)
8. "There is no evidence known to the authors which indicates that it is not at least possible that exercise of eye muscles such as that given in prolonged reading may not strengthen rather than harm the total visual mechanism." (sic) (p. 362)
9. "There is little evidence . . . which would make us believe that . . . older subjects or . . . subjects selected in some other way . . . would alter the present results . . . ." (p. 362-363)
10. "(I)n the case of subjects . . . whose eyes required refractive correction . . ., no special disadvantageous effects . . . were discovered." (p. 363)
11. "(T)here seems to be no basis for the belief that . . . long periods of reading (under optimal conditions?) . . . may be injurious to the visual mechanisms . . . ." (p. 363)
12. While "the present experiments do not allow the plotting of a 'feeling of fatigue' curve," subjective responses indicated that "satisfyingness decreased (while) accomplishment remained constant." Also, some subjects seemed "to like the long continued work of reading." (p. 366)
13. "(T)here is a specificity of fatigue of . . . systems which has . . . very little transfer to other comparable mechanisms." (p. 368)
14. "(C)hanges in the visual system following prolonged work may include an alteration on the part of the subject in his attitudes toward further work and in his description of his own feeling state." (p. 369)
15. Preliminary experiments, in which the subjects were given the simple task (no response motivation) of reading for four hours and until they were told to stop, resulted in a decrement "especially noticeable . . . in the tendency of subjects to stop reading for a few seconds or to allow the eyes to roam over the pages without reading." (p. 369)

"A conclusion which can be drawn from . . . these . . . experiments . . . and which also finds support in the literature . . . is summed up in the following . . .: In the use of a mechanism as well protected against the deleterious effects of the prolonged work of

normal reading as is the visual mechanism, the first index of fatigue seems to come in the alterations of the general attitudes and general feelings of the subject, not in a breakdown of the sensory-neuromuscular mechanism which actually performs the task. . . At the same time, it . . . also demonstrated a . . . more objective characteristic of the oncoming of fatigue, namely, the so-described starting and stopping phenomenon of temporary blockings, fluctuations, or the on and off effects in the performance of reading . . . . Finally, the most constructive aspect . . . may well be the demonstration of the ease with which well-considered alterations of the motivational pattern --- in this instance through the introduction of regularly interspersed tests of comprehension --- may forestall these first phases of fatigue and enable the individual to maintain for hours a high level of efficiency in reading." (p. 370-371)

* * *

3266 Case-1952

Case, Harry W., Michael, J. L., Mount, George E.
and Brenner, Robert
California U., Berkeley
ANALYSIS OF CERTAIN VARIABLES RELATED TO SIGN LEGIBILITY
In ROAD USER CHARACTERISTICS, Highway Research Board
Bulletin 60, (Washington, D.C., National Academy of Sciences-
National Research Council Publication 244, 1952), p. 44-58, refs.

Problem: "The recent development of high-speed urban freeways has increased the need for destination signs of maximum legibility." (p. 44) With this problem in mind, "determine (in a field situation) whether or not outdoor, daylight letter legibility varies with letter-background arrangement, and in turn how this letter-background legibility is influenced by spacing between letters and rows." (p. 44)

Procedure: Three-inch high, BPR SERIES E, rounded capital letters, with a stroke-width approximately one-sixth of letter height, were used, but only the letters B, C, D, E, F, O, P, and R. Altogether, there were twenty matched pairs of letter groups, half being spaced 1-1/2 inches between the letters and 2 inches between rows, the other half being spaced 4 inches between both letters and rows. Stimuli were shown in both black-on-white and white-on-black to four groups of college, summer-student subjects in a shutter-type tachistoscope, at distances ranging from 220 to 355 feet. Prior to the experimentation, the authors made a survey of the literature, which "revealed nine published studies in which the legibilities of (the) combinations (discussed above) were systematically compared." (p. 44) (see Aldrich-1937 and Forbes-1951, elsewhere in this handbook, and also see T. W. Forbes, A method for analysis of the effectiveness of highway signs, Journal of Applied Psychology, v. 23 (1939) 669-684; T. W. Forbes and R. S. Holmes, Legibility distances of highway destination signs in relation to letter height, letter width, and reflectorization, HRB

Proceedings, v. 19 (1939) 321-335; H. F. Janda and W. N. Volk, Effectiveness of various highway signs, HRB Proceedings, v. 14 (1934) 442-447; A. R. Lauer, Improvement in highway safety, HRB Proceedings, v. 12, part I (1932) 389-399; A. R. Lauer, The effect of increased illumination on acuity readings of singly exposed letters at different distances, Year Book of Optometry, 1942, 225-232; J. Otuka and T. Honda, Relationship between visual acuity and contrast under several light intensities, Acta Societatis Ophthalmologicae Japonicae, v. 44 (1940) 2253-2259; and W. W. Wilcox, The basis of the dependency of visual acuity on illumination, Proceedings of the National Academy of Sciences, v. 18 (1932) 47-56)

Result: "The results indicated that the widely spaced letters were more legible than those closely spaced, and that the legibility of the black-white arrangement as compared with the white-black arrangement was dependent on the letter spacing . . . (p. 53) Black letters on white background (was) the most legible arrangement when the letters (were) closely spaced, but this (was) not true when the letters (were) widely spaced. It may even be that white letters (would be) superior when wide spacing is involved. . . (p. 49) (These) interaction(s were) discussed in terms of irradiation and fixation fluctuations, and these concepts were then used to infer the effects of decreasing stroke width." (p. 53)

* * *

2622 Casperson-1950

Casperson, Roland C.

Johns Hopkins U., Baltimore, Md.

THE VISUAL DISCRIMINATION OF GEOMETRIC FORMS

Journal of Experimental Psychology,

40:5 (October 1950) 668-681, 16 refs.

Rept. no. 166-I-108, Special Devices Center

Contract N5-ori-166

Problem: "(D)etermine the discrimination thresholds of six different geometric forms (ELLIPSE, RECTANGLE, TRIANGLE, DIAMOND, CROSS, and STAR) and . . . relate their relative discriminability to three quantifiable aspects (area, dimension, and perimeter) of their construction." (p. 669)

Procedure: "(F)ive different figures for each form were constructed. . . (that) differed in maximum dimension and perimeter. . . (E)ach set of figures was reproduced at seven different areas . . ." (p. 669) thus providing a total of 210 different figures. "The seven areas used were .032, .072, .128, .200, .288, .512, and .800 (square centimeters)." (p. 670) For the smallest area, the following maximum diameters (MD) and perimeters (P) were used (in centimeters for the .032 square centimeter area---other areas are enlargements of the basic figure set---multiply MD and P by 1.5, 2, 2.5, 3, 4, and 5):

| | ELLIPSE | RECTANGLE | TRIANGLE | DIAMOND | CROSS | STAR(6) |
|---|---|---|---|---|---|---|
| 1. | | | | | | |
| MD | .202 | .254 | .272 | .254 | .240 | .235 |
| P | .662 | .716 | .817 | .716 | .882 | .720 |
| 2. | | | | | | |
| MD | .269 | .287 | .311 | .311 | .258 | .272 |
| P | .683 | .766 | .828 | .745 | .985 | .944 |
| 3. | | | | | | |
| MD | .310 | .327 | .373 | .358 | .318 | .304 |
| P | .748 | .828 | .890 | .803 | 1.242 | 1.112 |
| 4. | | | | | | |
| MD | .414 | .373 | .411 | .414 | .411 | .334 |
| P | .949 | .897 | .995 | 1.035 | 1.635 | 1.391 |
| 5. | | | | | | |
| MD | .518 | .421 | .455 | .518 | .534 | .433 |
| P | 1.157 | .983 | .992 | 1.064 | 2.132 | 2.099 |

(above from p. 670)

In the experiment, 20 male student subjects (normal acuity by AO test chart---no astigmatics) viewed stimuli (sets of cards, each consisting of nine, solid black, geometric figures randomly arrayed on a semi-gloss, white card at 2-inch centers in columns and rows of three each) from a comfortable chair having arm and chin rests, at 20 feet from the open end of a five-sided, three-foot-cube box (stimulus card at far end). "Each time a figure was repeated it appeared in a different relation to the surrounding figures and in a different orientation." (p. 671) Illuminance on each card was 11.2 foot-candles. A total of 100,800 individual responses were made by all subjects for all stimuli. Accuracy was the test criterion, although "(t)he (subjects) were advised not to spend too much time on any one figure and the method of forced guesses was used." (p. 671)

Result: The "frequency and percent of reports for each form regardless of accuracy (theoretical chance percent based on the number of forms = 16.7)" (p. 672) was as follows:

| | ELLIPSE | RECTANGLE | TRIANGLE | DIAMOND | CROSS | STAR | total |
|---|---|---|---|---|---|---|---|
| f* | 21,607 | 17,258 | 19,619 | 14,591 | 14,919 | 12,806 | 100,800 |
| %** | 21.4 | 17.1 | 19.5 | 14.5 | 14.8 | 12.7 | 100 |

* - f=frequency; ** - %=percent

Specific results of the experiment are as follows:

1. "Area was found to be the best measure of discriminability for ELLIPSES and TRIANGLES.
2. "Maximum dimension best predicted discriminability for RECTANGLES and DIAMONDS.
3. "Perimeter was the best predictor for STARS and CROSSES.
4. "As a group the six basic forms can be evaluated best for discriminability when their maximum dimensions are known.
5. "Prediction of discriminability for the total of 30 forms and figures was best accomplished on the basis of their perimeters.
6. "Comparison of the relative discriminability of the six forms used in this

experiment in terms of thresholds and total percent of correct reports confirms earlier findings that the CIRCLE and elliptical shapes in general are not very easy to identify.

7. "These results indicate that the Gestalt principle of 'simplicity' is inadequate as a predictor of the relative discriminability of ELLIPSES, RECTANGLES, TRIANGLES, DIAMONDS, CROSSES, and STARS such as those used in this experiment.
8. "A comparison of the variance contributed by the 20 (subjects) with the variance due to form differences substantiates the hypothesis that forms do differ in their discriminability and that differences among individuals making the discrimination are small compared to these form differences." (p. 680)

* * *

3368 Chapanis-1949

Chapanis, Alphonse, Garner, Wendell R. and Morgan, Clifford T.
Johns Hopkins U., Baltimore, Md.
APPLIED EXPERIMENTAL PSYCHOLOGY: HUMAN FACTORS IN ENGINEERING DESIGN
New York, John Wiley & Sons, Inc., 1949, 434p.
("Legibility of Numbers, Letters, and Symbols," p. 170-180)

Extract: "A very important factor in most visual displays is the legibility of the numbers, letters, and symbols used. . . (T)here are some important perceptual problems involved in legibility too." (p. 170)

Confusion - "Capital O's and Q's . . . are very frequently confused when they are seen at a distance. A's and V's . . . are practically never confused." (p. 170)

Legibility Studies - "Most of the work on legibility has been done with different kinds of printer's type. . . Our summary of . . . recommendations . . . is taken from the books by Paterson and Tinker and Luckiesh and Moss." (p. 170-171)

Styles of Type Face - "GARAMOND, ANTIQUE, SCOTCH ROMAN, BODONI, OLD STYLE, MODERN, CASLON, CHELTENHAM, and KABEL LIGHT all (are read) about equally well. . . AMERICAN TYPEWRITER . . . definitely slows us down. . . OLD ENGLISH. . . has so many angles and curlycues that it slows readers down by about 14 percent." (p. 171)

Type Form - "(M)aterial in capital letters (is read) much more slowly than . . . in lower-case . . . (O)bjective tests . . . agree with how readers feel about it. . . The reason is probably that we destroy word form when we use capitals. . . Bold-face type is read about as well as ordinary type. Most people, however, do not like . . . it . . . (R)estrict the use of italics and bold-face printing to short sections which require emphasis." (p. 171)

Type Size, Line Width, and Leading - "(T)hese factors are interrelated. . . When the best line widths and leading are used . . ., it appears that 9-, 10-, 11-, and 12-point type sizes are about equally legible. Speed of reading is slowed down with 8-point type and markedly slowed with 6-point type." (p. 171)

Color of Print and Background - "(B)lack print on white is more legible than white on black. . . (W)hite on black (is) so illegible . . . that (it) should never be used where readability is important. . . (In) colored inks on different colored papers. . . the colors by themselves are not very important. The really important thing is the amount of brightness contrast between the letters and their backgrounds." (p. 172)

Legibility of Isolated Symbols - "(T)he total context of all the letters and words helps us to read rapidly. But many visual displays do not have whole words on them. . . Whenever single letters or numbers are used . . ., the legibility problem becomes more difficult." (p. 172-173)

Kinds of Seeing Conditions - "Instruments and dials sometimes have to be read when the light is very poor. Aircraft status boards, plotting boards, and highway signs have to be read from great distances. For many types of visual display, . . . we want . . . maximum legibility of single letters or symbols under unfavorable conditions." (p. 173)

Kinds of Performance Measured - "(T)he experiments to date did not measure as many things as we should like to have measured." (p. 173) Speed of reading and blink rate are the primary ones used until now. "(I)t is difficult to see what the blink rate has to do with legibility . . . ." (p. 173)

Basic Studies Versus Comparative Tests - "(C)omparative tests. . . do not get at the real factors that make symbols legible. . . All we can tell from the (readability) studies . . . is that certain kinds of type are more readable than others. We still do not know whether they are the best possible kind of type." (p. 173)

Factors Affecting Symbol Legibility - "(T)he simplicity of a number or letter markedly affects its legibility. Different amounts of shading, and different numbers of hair lines in numbers also make them harder or easier to read. So does the amount of white space included within the outline of . . . symbols. And finally, emphasizing certain parts . . . will make them much more readable. The B, for example, is a lot more legible if we put a little overhang on the top and bottom. The same is true of . . . D. . . (I)t (is) easier to distinguish C and G if we have well-marked gaps . . . and put a well-marked cross-piece in . . . G. The Q needs a definite strong oblique stroke so we will not confuse it with . . . O or C, and the W needs a high center prong so it will not look like an M. S is a difficult letter no matter what we do." (p. 174)

A Comparison of Letter Designs - "Mackworth . . . improv(ed) the legibility of letters and

numbers on sector maps used for air raids. . . (V)iewed . . . at 25, 30, 35, and 40 feet(, t)he average misreading errors at every distance (were) much lower for the new (MACKWORTH) design. . . (I)t is . . . easier . . . to tell the difference between the 'O' and 'Q,' the 'C' and 'G' and '6'." (p. 174)

The Best Stroke Width - "(T)hicker (U.S. Bureau of Public Roads) series D letters can always be seen farther away than the thinner (Series B) letters and . . . day vision is always better than night vision, as we might expect. . . In (an experimental) study, . . . the best stroke width was 18 percent of the height of the letter, which corresponds very closely to the one-sixth height of the series D letters . . . ." (p. 176)

The Most Legible Numbers - In a series of experiments "on automobile license plates. . . (numbers had outside dimensions of 42 by 80 millimeters, using the numbers 8, 5, and 2, because they are the hardest to identify correctly) the data show that 6 millimeters (was) the best stroke width for white numbers on . . . black . . ., but that 10 millimeters (was) the best width for (the opposite) . . . . (It is n)oted especially that the white numbers on the black background (were) recognized farther away than the black . . . on . . . white . . ., even when both (had) the best stroke width." (p. 177)

Numbers at Night - "In a(n) . . . experiment, . . . (it was ascertained that) luminous numbers can be seen better than those illuminated from the front (in white on black), but they also need a much smaller (1/80 as opposed to 1/10 the height) stroke width. . . The daylight . . . and the luminous (optimal) numbers . . . are shown . . . ." (p. 177-178)

Angle of Viewing - "(D)isplays should be placed perpendicular to the line of sight . . . ." (p. 178) The reasons for doing it are the avoidance of (1) distortion, (2) parallax errors, and (3) ease of reading (accommodation?). For the latter, "reading errors increase(d) for (MACKWORTH) . . . as the viewing angle change(d) from 90 to 35 degrees." (p. 178)

Further Research Needed - "The results of . . . studies . . . have not varied enough of the critical factors . . . to emerge with some . . . basic generalizations. We need . . . more basic studies, for example, in which the height . . . is kept constant while the width and stroke width are varied . . . . It is possible that there are some important interactions . . . We need . . . more basic studies on the effects of things like emphasizing certain parts of letters or numbers. . . Maybe the vertical lines need to be heavier . . . . Or vice versa. We need . . . research on the influence of 'overhangs' on certain letters, . . . and on the width of the white space in . . . letters . . . . And, finally, we need . . . basic research on symbols other than letters and numbers, like ARROWS, DASHES, PLUS MARKS, and so on. . . (U)ntil we have this . . we will not be able to tell you how to design the best possible symbols for visual displays." (p. 179)

* * *

2623 Chaundy-1954

Chaundy, Theodore W., Barrett, P. R. and Batey, Charles
THE PRINTING OF MATHEMATICS
London, Oxford University Press, 1954, 105 p.

Problem: Prepare a reference manual, i. e. a handbook of practice, for use by the authors, editors, and compositors of mathematical publications (specifically for use at the University Press, Oxford), including (1) information concerning confusable alpha-numeric characters and (2) a set of HANDPRINTED, "LATIN and GREEK alphabets, capital and lower-case, and also the ARABIC NUMERALS, . . . which . . . will minimize the danger of confusion . . . ." (p. 90)

Procedure: The following outline of contents indicates that the printing of mathematical works is necessarily of such an exactitude that there is little, if any, room for illegibility or confusion:

I. The mechanics of mathematical printing ("a simple explanation of the technique of printing . . . addressed to those . . . curious to know how . . . writings are transformed to . . . the printed page"). (p. v)
   - A. The hand compositor (letterpress method of printing, nature of type, and composing type by hand).
   - B. The machine compositor ('Monotype' keyboard and casting machine).
   - C. Composing mathematics on the 'Monotype' machine.
   - D. Making-up.
   - E. Making new matrices.
   - F. Imposition.
   - G. A note on offprints.

II. Recommendations to mathematical authors (to the mathematical author, editor, and reader).
   - A. Introduction (constraints of type, text and formulae, embellished characters, and consideration for the reader).
   - B. Fractions (the solidus, bracketing with the solidus, numerical fractions, and products of fractions).
   - C. Surds.
   - D. Superiors and inferiors (including commas, use of solidus, and correction signs).
   - E. Brackets (including symbolic and special uses).
   - F. Embellished characters.
   - G. Displayed formulae (including broken formulae and 'assertions', simultaneous equations, 'broken definition', 'broken inequalities', and economy).
   - H. Miscellaneous notation (abbreviations, binomial coefficients, definitions, limits, matrices and determinants, maxima and minima, products, unfinished series, vectors, and sign of substitution).
   - I. Headings and numbering (including sections, paragraphs, enunciations, numbering, equation numbers, and subsidiary results).
   - J. Footnotes and references.
   - K. Varieties of type (bold-face, italics, capitals, and special founts).
   - L. Punctuation (including the comma, full point, semicolon, colon, dashes, quotation marks, apostrophe, and hyphens).
   - M. Wording (including assertions, proofs, definitions, 'assume', 'arbitrary', 'or', 'as', 'only', 'I', 'we', 'can', 'may', 'will', 'shall', subjunctives, split infinitives, unattached participles, and 'combined operations').
   - N. Preparing copy (confusable characters, mathematical notation, typescript, special symbols, text-figures, tables, and final precautions).

O. Correction of proofs (including errata and corrigenda).
P. Final queries and offprints.

III. Rules for the composition of mathematics at the University Press, Oxford (intended for compositors, readers, authors, and editors).
A. General.
B. Formulae.
C. Spacing.
D. Marks used in correction of proofs.

Appendix A. Legible HANDWRITING.

Appendix B. Type specimens and list of special sorts.

1. Founts and accents used in mathematical composition.
   a. MODERN SERIES 7: 11-, 9-, and 8-point.
   b. MODERN SERIES 7: 11-, 9-, and 8-point italic kerned caps.
   c. MODERN SERIES 18: 6-point.
   d. MODERN SERIES 16: 5-1/2-point.
   e. MODERN SERIES 26: 5-point.
   f. BOLD FACE SERIES 53: 11-, 9-, and 6-point.
   g. BOLD SCRIPT: 11-point.
   h. GILL SANS SERIES 262: 10-point caps.
   i. GILL SANS BOLD SERIES 275: 10-point caps.
   j. GREEK SERIES 106: 11-, 10-, 8-, and 5-1/2-point.
   k. GREEK SERIES 90: 11-, 9-, and 6-point.
   l. GREEK SERIES 91: 11-point.
   m. GREEK UPRIGHT DISPLAY SERIES 92: 11- and 9-point.
   n. KERNED CAPS: 11-point.
   o. FRAKTUR SERIES 28: 10-, 9-, and 6-point.
   p. FRAKTUR SERIES 29: 10-, 9-, and 6-point.
   q. SCRIPT (including superiors and inferiors): 11-point.
   r. SCRIPT CAPITALS 8/9.
   s. SUPERIORS and INFERIORS: 11- and 9-point.
2. SYMBOLS used in mathematical composition (117 symbols in 11-, 10-, 9-, 8-, and 6-point).
3. DISPLAY SYMBOLS (12 symbols in 48-, 42-, 36-, 30-, 24-, 20-, 18-, and 14-point).

Appendix C. Abbreviations.

1. Names of units.
2. Names of periodicals.

Confusion data and an optimal handprinted character set are reported in section III. N. (preparing copy), and appendix A., respectively.

Result: Confusion and ambiguity may arise in the following cases:

1. "Greek and italic: $\alpha$, a, d; $\gamma$, y, Y; $\epsilon$, e; $\eta$, y; $\kappa$, k, K; $\mu$, u; $\nu$, v, r, $\Upsilon$; $\sigma$, o; $\chi$, X; $\omega$, w, W."
2. "Numeral and italic: 0, o, O; 1, i, I, typed l; 2, 3, z."
3. "Capital and lower-case: C, c; O, o; S, s; U, u; V, v; W, w; X, x; Z, z; $\Theta$, $\theta$; $\Phi$, $\phi$; $\Psi$, $\psi$."
4. "In some hands the pairs h, n; e, l; n, x; n, r; r, s; m, n may be confused."
5. A ". . . new (i.e. novel) symbol should be 'seeable' . . ." in order to be legible and might possibly better come from existing fonts of type (even in foreign alphabets "such as HEBREW or GAELIC").
6. "(I)nversion of symbols to form new symbols is not recommended . . . ." (p. 66-68)

A "legible" HANDPRINTED character set (shown in appendix A) is as follows:

LATIN CAPITALS:

ABCDEFGHIJKLMNOPQRSTUVWXYZ

LATIN LOWER-CASE:

abcdefghijklmnopqrstuvwxyz

GREEK CAPITALS:

ΑΒΓΔΕΖΗΘΙΚΛΜΝΞΟΠΡΣΤΥΦΧΨ

GREEK LOWER-CASE:

αβγδεζηθικλμνξοπρσςτυφχψω ϖ

ARABIC NUMERALS:

1234567890

* * *

2625 Coffey-1961

Coffey, John L.

Battelle Memorial Inst., Columbus, Ohio

A COMPARISON OF VERTICAL AND HORIZONTAL ARRANGEMENTS OF ALPHA-NUMERIC MATERIAL--EXPERIMENT 1

Human Factors, 3:2 (July 1961) 93-98

Also available as RADC-TR-60-201,

Contract AF 30(602)-2078

Problem: "(D)etermine the relative effectiveness of visual displays containing alpha-numeric material displayed in vertical and horizontal arrangements. Variables included in the experimental design were: types of arrangement of display material, composition of material, and operator tasks." (p. 93)

Procedure: "The experimental design . . . was a . . . complete factorial with 12 (male, age 22-33, and with a minimum education of high school) subjects . . . The variables in the design were: (1) two types of arrangement---horizontal and vertical; (2) two density levels---one column or row and three columns or rows; (3) four compositions of alpha-numeric material---letters, numbers, letters and numbers combined, and two-letter words; and (4) four subject tasks---counting, locating, identifying, and comparing. . . Sixteen original formats were prepared. Four of these formats contained only letters . . .; four . . . only numbers . . .; four . . . only letters and numbers . . .; and four . . . contained only two-letter words(, each of the above being) in different arrangements and density. . . (p. 93) The subject's desk chair was placed 5 (feet) in front of (a) screen. All projected alpha-numeric characters were approximately 1/2 (inch) in height. The center of the projected display was 47 (inches) from the floor." (p. 95)

Result: "It was found that subjects performed better with words than with other types of

alpha-numeric materials. This probably can be attributed to the greater meaningfulness of words. As would be expected, the higher density condition degraded subject performance. With regard to subject tasks, locating and comparing resulted in significantly better performance scores than did counting and identifying. . . The major finding in the study was the non-significance of the arrangement variable. According to the results of the present study, the design engineer can assume that, for all practical purposes, the differential effects of horizontal and vertical arrangement of alpha-numeric material on operator performance are negligible." (p. 98)

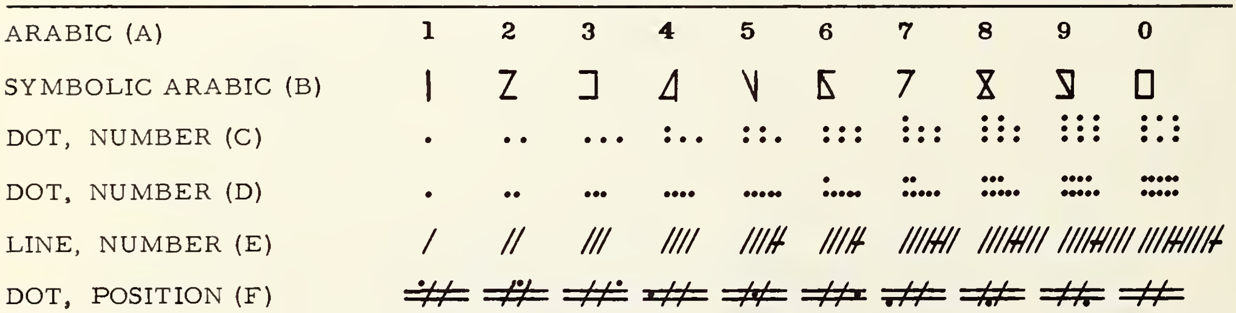
* * *

2626 Cohen-1953

Cohen, Jerome and Webb, Wilse B.
Antioch Coll., Yellow Springs, Ohio
AN EXPERIMENT ON THE CODING OF NUMERALS FOR TAPE PRESENTATION
WADC Technical rept. 5486, Dec 53, 14p., 3 refs.
Contract AF 18(600)-50
AD-43 529

Problem: "One way of transmitting information to aircraft crews would be to automatically punch or print numerical (and/or digital?) information on tape in the airplane in response to radio or radar signals. . . A compromise system of marking the tape . . . (would have to be) efficient for both mechanical . . . scanning.". . (p. iii) and weight requirements as well as for human reading. With these criteria in mind, determine the difference between "ARABIC numerals and five systems of coded numerals.". . (p. iii) in speed and accuracy of reading.

Procedure (primary experiment): Twenty-four college students---age 16 to 24---in 6 groups of 4 each, were tested on the following codes (simulated here):




(above from p. 3)

"(S)ubjects were tested individually while sitting at a table with the experimenter." (p. 2) The task was to read the number on a card, and then turn to the next card in the deck of 100 cards for each code. Subject had reference to the instruction sheet during the course

of being tested. Codes were not mixed within a deck. However, the order of presentation of codes to subjects was random. "All subjects were tested on all codes." (p. 2) Accuracy and speed were recorded.

Result (primary experiment): The following were read significantly faster (at the 0.1 percent level of confidence) than others as shown by asterisks (*).

| code read faster than: | B | C | D | E | F |
|---|---|---|---|---|---|
| A | * | * | * | * | * |
| B | | * | * | * | * |
| C | | | | | * |
| D | | | | | * |
| E | | | | | * |

"If engineering considerations make it unfeasible to build a lightweight scanner to interpret the conventional ARABIC numerals, then a (six line element) numeral system analogous to our code B should be considered. . . (p. 8) Another possibility would be to have a dual system, so that a simple dot (or binary?) code could be used by the mechanical scanner, while the Arabic code could be superimposed on the tape for human scanning. . . It seems to make little difference whether the elements are dots or lines but presumably the elements should be patterned to aid in the identification of visual number." (p. 9) For accuracy of reading, the following rank was found: A, B, E, F, C, and D. However, "(o)nly 1.88 (percent) of the 12,000 numerals were read incorrectly, so an extensive analysis of the particular error producing features of the codes is not possible. However, two outstanding sources of error (were) apparent . . . . Half of the errors in code B involved the numeral '4' . . . confused with '5'. Confusion between the '0' and the '9' account(ed) for one third of the errors in code D. . . (C)ode D would be considerably more accurate without a zero, but the . . . zero did not materially affect the accuracy of the other codes. However, codes like C, D and E would all be improved if in actual use a blank space in the proper column would designate zero rather than a symbolic presentation." (sic) (p. 9)

Procedure (corollary experiment): "Since the accuracy of code D was materially affected by the omission of zero numbers, . . . (e)ight additional subjects were run on 100 cards of codes B and D from which zero numbers were omitted." (p. 9)

Result (corollary experiment): "(M)ean reading time(s) . . . were similar to the means of the previous experimental groups and in favor of code B." (p. 9) Significance was "at the 5 (percent) point . . . Further experimentation should be done with actual tapes . . . in a (simulated) real(ity) situation in order to test the merits of a code like D or E in presenting a graphical picture." (p. 9)

Result (developmental): The following is a suggested symbolic alphabet, requiring an eight element printer, for use in "the tape presentation of verbal information.". . (p. 14) (simulated here):


* * *

2170 Colgate-(1955)

Colgate U., Hamilton, N. Y.

LEGIBILITY OF SYMBOLS OF THE AND10400, MACKWORTH, AND BERGER TYPE-FACES AT VERTICAL AND HORIZONTAL ANGLES OF PRESENTATION AND THE CONSTRUCTION AND TEST OF LEGIBILITY OF A REVISED TYPE-FACE

Final rept., undated, 37 p., 10 refs.

Contract AF 30(602)-212

RADC TR 55-78; AD-75 629

Problem: "Because of spatial restrictions, individuals employing visual displays as sources of information often must be displaced from the axis normal to the plane of the display-panel. Understanding the effects of such angular displacement upon legibility was the general aim of this investigation. More specifically the research was directed toward: I. Measurement of variation in legibility of symbols at several horizontal and vertical angles of presentation, II. Comparison of the legibility of three representative systems of type-face at the several angles of presentation, III. Comparitive legibility of each of the homologous symbols of the three type-faces, IV. Analysis of the frequency and nature of error-responses given to each symbol (confusion), V. From III and IV, determining the characteristics of symbol construction which contribute to legibility and reduce confusions, VI. From the results of (V), construction of an improved type-face, and VII. Measurement of legibility of the REVISED type-face at several horizontal and vertical angles of presentation." (p. i)

Procedure (AND10400, MACKWORTH, and BERGER faces): "All letters and numerals of the AND10400 and MACKWORTH type-faces, and numerals of the BERGER constituted the test-material. The symbols were reproduced individually, 3/16 (inches) high, white on black, on dull finish photographic paper. Obtaining constant brightness and brightness contrast for all angles of presentation was . . . solved . . . by proper selection of reproduction paper and placement of illuminating sources. . . the light rays (being) so directed that varying angles of reflectance to 0 produced little variation in brightness. . . The method of limits was employed to obtain from 10 . . . (subjects) individually, distance-limits (in feet) for each symbol presented at (0, 15, 30, 45, 60, and 75 degrees),

horizontally and vertically. Error responses elicited to each stimulus-symbol before the limit of correct identification was reached, were recorded to be used in an analysis of relative confusion. Statistical and mathematical treatment: Mean distance-limits were computed for several combinations of data, converted into conventional visual acuity units ---visual angle, and plotted graphically. The error-responses to each symbol were tabulated both as to total frequency and the frequency of each specific error-symbol to each stimulus-symbol." (p. i)

Result (AND10400, MACKWORTH, and BERGER faces): The "(g)eneral findings were as follows:

1. "Legibility of symbols on planes displaced from the normal varied according to an exponential cosine function of the angle of displacement. In terms of mean distance-limits, for horizontal and vertical angles the exponents were 2/3 and 1/2 respectively, increasing vertical angles producing a smaller decrement in legibility than equivalent horizontal angles; in terms of visual angle, the reciprocal of the cosine of the angle described the data.
2. "(a) There was no significant difference between the all-symbol, all-angle mean distance-limits of the AND and MACKWORTH type-faces; (however, ) the numerals of both . . . yielded higher mean distance-limits than the BERGER numerals. (b) Comparison of the type-faces(, ) based on the number of symbols whose all-angle mean distance-limits reached or exceeded one standard deviation above or below the average(, ) . . . favored slightly the AND . . . over the MACKWORTH, and both . . . over the BERGER numerals.
3. "Comparison of mean distance-limits for homologous symbols at all angles and at each angle of presentation, revealed more instances of higher mean limits for the AND homologous than for the MACKWORTH. By a similar comparison, the BERGER numerals were inferior to both . . . .
4. "(a) The average number of confusions per symbol were quite equal for the three type-faces studied. (b) There were, however, widespread differences in the frequencies and nature of confusions to each of the symbols within each type-face and between homologues of the type-faces. (c) Comparisons of frequencies of error-response to each symbol using both standard deviation and homologue criteria indicated a slight superiority (in terms of number of superior symbols) of the AND over the MACKWORTH type-face, and the numerals of both . . . over the BERGER numerals.
5. "On the basis of higher mean distance-limits (greater legibility) and fewer error-responses (less confus(a)bility), the superior homologues of the type-faces were isolated. Examination of the stroke-composition of these as compared to their inferior homologues revealed characteristics of design, both individually and generally, which contribute to legibility.
6. "A system of type-faces was constructed in which the strokes, characterizing and distinguishing each symbol, were emphasized or accented in one or more ways:

width, length, intersection, relative position, curvature." (p. i-ii)

Procedure (REVISED experimental face): An experimental REVISED type-face (referred to in 6. above) was "reproduced in the same manner as the symbols in the (above) study and subjected to tests of legibility at five angles of presentation---(0, 30, and 60 degrees), horizontally and vertically. The symbols of the AND10400 system, as a standard of comparison, were retested with the revised. The method, procedure, and treatment of data closely followed the pattern of the (above) study." (p. ii)

Result (REVISED experimental face): "High correlation coefficients (approximately 0.80) between mean limit-distances . . . , and between frequencies of error-response for AND symbols of the (above) and (of this) stud(y), demonstrated a high reliability of method." (p. ii) Specific findings were as follows:

1. "The mean limit-distance data of the REVISED type-face and retest data of the AND type-face were described by the same mathematical function (exponential cosine formula) relating legibility to increasing angle of presentation, that held for the (above) study.
2. "(a) The REVISED system yielded higher all-angle, all-symbol mean distance-limits than did the AND system. Also the REVISED all-symbol mean limits were higher at each of the five (sic) angles of presentation. (b) Comparison of the type-faces based on the number of symbols whose all-angle mean limits reached or exceeded one standard deviation above or below the average . . . definitely favored the REVISED system.
3. "Comparison of mean distance-limits for homologous symbols at all angles and at each angle of presentation, revealed many more instances of higher mean limits for the REVISED than for the AND homologues.
4. "(a) The symbols of the REVISED type-face in toto, elicited about 10 (percent) fewer error-responses than did the symbols of the AND. (b) Correlation coefficients of over -.80 (for both systems) between error-responses and all-angle mean distance-limits indicated that the two indices were inversely correlative measures of symbol legibility. (c) Comparisons of frequencies of error-response to each symbol using both standard deviation and homologue criteria favored the REVISED system---less confus(a)bility.
5. "The data reveal(ed) that the all-angle mean distance-limit of a symbol is a reflection of its each-angle data accumulatively; symbols which are significantly superior in all-angle legibility tend to have good legibility at each angle. Intercorrelations between symbol-data for each of the angles of presentation yield high coefficients and tend to confirm the internal consistency. It can be generalized that characteristics of symbols which contribute to legibility at any one angle of view contribute to legibility at all other angles." (p. ii-iii)

Result (overall): "It can be concluded that: 1) Legibility of symbols decreases according

to an exponential cosine function of the angle of displacement; and, employing this as a principle of application, observers angularly displaced from a visual display panel can be situated appropriately, providing them with conditions for legibility equal to the centrally located observer. 2) It is possible to improve legibility of type-faces by determining and accenting those characteristics of symbol construction which contribute to correct identification and low confus(a)bility. A step in this direction (has been) demonstrated by the improved legibility of the REVISED system of type-face." (p. iii)

* * *

3263 Craik-1943

Craik, K. J. W.
Flying Personnel Research Committee (Gt. Brit.)
LEGIBILITY OF DIFFERENT COLOURED INSTRUMENT
MARKINGS AND ILLUMINATED SIGNS AT LOW ILLUMINATIONS
Rept. no. F.P.R.C. 415, Jan 43, 3p.
AD-102 931

Problem: Discuss the effect of various colors of fluorescent paint on the legibility of instrument markings and illuminated signs at low levels of illumination. "Luckiesh and Moss have pointed out that blue or green fluorescent figures may be blurred for distant vision . . . though the effect is not very serious . . . (H)owever, . . . the effect can become serious with some of the blue-filtered tungsten lamps used for illuminated signs . . . render(ing) them far less legible than red ones of comparable brightness . . . (T)his phenomenon may possibly account for the superiority of a -1 (dioptre) focus for night glasses . . . ."

Procedure: A number of experiments were conducted at brightnesses low enough to be comparable to instrument-panel night-lighting. These included (1) a photometric match with a 1 (degree) field, (2) the Bishop Harman test, (3) experiments with colored stencils and fluorescent paints, (4) tilting parallel lines of paint, under ultra-violet illumination, until they fuse together, and (5) time required (by three subjects) to pick up aircraft silhouettes projected on a screen in a comparison of mock-up blind flying panels for their "dazzle" effect. The last two techniques specifically were utilized because it was determined that the "(p)hotometric comparison of different colours at low brightnesses with small fields . . . is unsatisfactory, . . . (t)he final criterion of the permissible brightness of instrument markings (being) not their brightness but their dazzling effect."

Result: In these experiments, an inferiority, similar to that found by Luckiesh and Moss, "of blue and green fluorescent paints in legibility has been found even at distances of 18 inches, where the accommodative power of the normal eye can compensate for the maximum chromatic aberration of 2 dioptres. Figures in radio-active luminous paint or green

fluorescent paint (Type F) required to be approximately 50 (percent) larger for equal legibility at equal brightness . . . or alternatively required to be about 70 (percent) brighter to give equal legibility. The green figures had a very blurred appearance and a tendency to fuse together or diverge in the Bishop Harman test much more readily than orange or red figures. This blurred appearance was . . . found . . . to be due to the colour (rather than to a lack of background to enable the eyes to accommodate) . . . ." In the mock-up panel experiment, "the green one was found to produce significant delay . . . while the orange did not. For orange paint, brightnesses up to .005 (effective foot-candles) appear safe from dazzle. The upper brightness limit of the present fluorescent system is probably necessary under exceptional conditions (e.g. with moonlight outside the aircraft and the panel in shadow), but the brightness should always be set to the least necessary." The "results have confirmed the good visual qualities of the orange fluorescent paint used in the system of lighting evolved by the . . . R.A.E." However, "while orange is markedly superior (to green) . . . , it is probable that a bright red fluorescent paint would be better still, and would have the added advantage of . . . avoiding all chance of impaired dark adaptation." The current drawback to red is that "(t)he G.E.C. red powders available in this country (Great Britain) are insufficiently bright."

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2627 Crannell-1958

Crannell, Clarke W. and Debons, Anthony

Miami U., Oxford, Ohio and Aero Medical Lab.,

WADC, Wright-Patterson Air Force Base, Ohio

ILLUMINATION AND TILT AS FACTORS IN THE LEGIBILITY OF REFLEX-REFLECTIVE NUMERALS

WADC Technical rept. 58-47, Sep 58, 21p., 2 refs.

Contract AF 33(616)-2844

AD-142 327

Problem: Determine the effect of variations in distance, orientation, and illumination on the "legibility of AND 10400 digits under nighttime conditions . . . using four different sets of all ten digits . . . ." (p. 14)

Procedure: A total of 27 male subjects viewed, by groups and at night, "black digits on aluminum background, black digits on white painted background, black digits on reflex-reflective background, and reflex-reflective digits on black background. . . Three experiments were conducted: (1) with digits at four different distances (256, 320, 400, and 500 feet) from the observers and at 90 (degrees) to the line of sight, and also tilted at angles of 60 (degrees), 40 (degrees) and 27 (degrees) to the line of sight; (2) at three different distances (256, 320, and 500 feet) and with digits simultaneously turned and tilted from the line of sight . . . (p. 14) For (this) study . . . (, t)he number of degrees of turn,

60 (degrees), 40 (degrees) or 27 (degrees), was always equal to the number of degrees of tilt . . . ; (p. 4) and (3) at a distance of 500 (feet) when the level of illumination was increased by moving the spotter lamp closer to the display (and thus varying brightness from 0.07 to 0.52 foot-lamberts, depending on the distance and viewing angle)." (p. 14) Digits were all 12 inches tall, 8 inches broad (except for "1"), and 1.5 inches in stroke-width. The experiments were performed (statically) to simulate the (dynamic) condition in which an interceptor aircraft overtakes an unidentified aircraft and wishes to identify it by the numerals normally found on aircraft vertical stabilizers.

Result: "Under nighttime conditions reflex-reflective digits (were) more legible than the other display conditions at the greater distances, and at the closer distances when the digits (were) tilted or turned from the perpendicular to the line of sight. . . Comparison with . . . previou(s) . . . experiments . . . indicate(d) that tilting the digits to the line of sight yield(ed) about the same reduction in visibility as turning them from the line of sight. However, when the plane of the digits was displaced both vertically and horizontally from the line of sight, legibility was seriously impaired for all types of materials. An increase of intensity of illumination was found to have little or no effect upon legibility when the display was viewed from 500 (feet). With the size and strokewidth used, digit 8 (was) least legible." (p. 14)

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2629 Crook-1947a

Crook, Mason N., Hoffman Arthur C., Wessell, Nils Y.,
Wulfeck, Joseph W. and Kennedy, John L.
Tufts Coll., Medford, Mass.
PRELIMINARY STUDIES OF THE EFFECT OF VIBRATION,
ILLUMINATION AND TYPE SIZE ON LEGIBILITY OF NUMERALS:
EFFECT OF VIBRATION ON LEGIBILITY OF TABULAR
NUMERICAL MATERIAL, EXPERIMENTS 1 TO 4
Report on Aviation Psychology Project Rept. no. 1, May 47, 20 p.
Contract W33-038 ac-14559
Aero Medical Lab. Memorandum rept. no. TSEAA-694-1F; ATI-64 451

Problem: Determine the effect of (1) amplitude of linear surface vibration, (2) brightness level, (3) type size, (4) orientation of the characters, and (5) interactions between some of these on the legibility of numeric characters that simulate those normally found on charts, instruments, manuals, tables, and other visual aids.

Procedure: Six to twelve male subjects between the ages of 20 and 25 (and having binocular visual acuity of 20/25 or better) participated in four experiments. The task was to read a series of black-on-white, paired digits and determine whether they were the same or

different, with response being the actuation (by the subject) of one of two finger keys. Horizontal linear vibration (induced by means of Risley prisms which rotated in the 14-inch space between the eyes and the stimulus) was varied from 0.0079 to 0.079 inches of double amplitude (distance between extremes of the excursion). Brightness of the reading material ranged approximately from 1 to 13 foot-lamberts. Type size varied from 6 to 11 points. Orientation of the characters was upright or upside down. Interactions between variables were as follows: experiment one - amplitude of vibration and brightness, experiment two - amplitude of vibration and type size, experiment three - same as experiment two but with the reading material inverted, and experiment four (performance under extreme conditions) - a favorable combination compared with an unfavorable combination of vibration, brightness, and type size. Accuracy and speed were the test criteria in all experiments.

Result: Major research findings were as follows:

1. Vibration amplitude of 0.08 inch resulted in significantly slower reading than 0.02 and 0.008 inch. However, there was no significant difference in accuracy.
2. Brightness variations between 12.4 and 0.96 foot-lamberts gave no significant difference in either accuracy or speed.
3. Inverted 6-point type was read with less accuracy and speed than other sizes inverted. For upright reading, there was no significant difference between sizes.
4. The unfavorable combination, when compared with the favorable combination of vibration, brightness, and size, increased error rate by approximately 150 percent and speed by approximately 40 percent.

Thus, it may be concluded (from the above and other experimental results shown) that (1) the effect of vibration amplitude was roughly comparable to the effects of brightness and type size, and (2) a combination of unfavorable values of the variables used may go beyond a subject's capacity to adjust to the impairment.

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2120 Crook-1947b

Crook, Mason N., Hoffman, Arthur C., Wessell, Nils Y.,
Wulfeck, Joseph W., and Kennedy, John L.
Tufts Coll., Medford, Mass.
FURTHER STUDIES OF THE EFFECT OF VIBRATION AND
OTHER FACTORS ON LEGIBILITY OF NUMERALS;
EFFECT OF VIBRATION ON LEGIBILITY OF TABULAR
NUMERICAL MATERIAL, EXPERIMENTS 5 TO 7
Report on Aviation Psychology Project
Rept. no. 4, Aug 47, 17 p.
Contract W33-038 ac-14559
Aero Medical Lab. Memorandum rept. no.
TSEAA-694-1K; ATI-14 243

Problem: Determine the following:

1. "Effect of vibration frequency on legibility under favorable conditions of amplitude, brightness, and numeral size, and under unfavorable conditions of these same secondary variables.
2. "Effect of different vibration patterns (i.e., linear, rotary, and elliptical) on legibility under two conditions of amplitude and with brightness, numeral size and vibration frequency held constant.
3. "Relative legibility of white numerals on a black background (versus) black numerals on a white background." (p. 1)

Procedure: "All studies were made under simulated daylight conditions. . . (p. 1) The reading material consisted of a series of pairs of digits. The subject's task was to judge whether the two members of a pair were the same or different, indicating his judgment by finger keys. . . Subjects were male college students with visual acuities 20/25 or better at the experimental reading distance, 14 inches." (p. 6-7) In Experiment 5, "(t)hree frequencies were used, 480, 930, and 1830 per minute. . . (T)he 930 and 1830 were within . . . the range of frequencies most commonly encountered (in aircraft). With respect to the other stimulus variables, two conditions were established. The favorable condition . . . included the following values: amplitude, 0.0079 inch (double amplitude of linear horizontal vibration); brightness, 14.7 foot-lamberts; type, 11 point. Values for the unfavorable condition . . . were: amplitude, 0.079 inch; brightness, 1.12 foot-lamberts; type, 11 point. . . Six subjects . . . served . . . ." (p. 9) In Experiment 6, "(t)wo sets of form patterns were used, alike except for amplitude level. Each set included one linear pattern, two ellipses, and one circle. In set no. 1, the linear amplitude was 0.032 inch. The two ellipses had major axes equal to the linear amplitude and minor axes of 0.010 and 0.021 inch. Diameter of the circle was the same as the linear amplitude. . . In set no. 2, dimensions were one half of set no. 1 . . . . Each of the other stimulus variables was held constant at an intermediate value: vibration frequency, 1380 per minute; brightness, 5.69 foot-lamberts; type, 8 point." (p. 12) Four of the previous six subjects participated. In Experiment 7, "(r)eading material was prepared in white on black, otherwise identical with the black on white regularly used. Type size was 11 point." (p. 14) Also, because of experimental limitations, "the subject . . . (was) presented with an areal contrast condition in addition to the demands of the reading task. . . The linear vibration pattern only was used. With respect to other variables, two conditions were set up: the (unfavorable) condition was analagous to the (same) condition of Experiment 5; the (favorable?) condition was mixed, being favorable in brightness and frequency but unfavorable in amplitude. Values were as follows: (unfavorable) condition--amplitude, 0.074 inch; frequency, 1380 per minute; brightness, 1.12 foot-lamberts; (favorable?) condition--amplitude, 0.11 inch; frequency, 480 per minute; brightness, 14.7 foot-lamberts. . . Four new subjects were trained for this experiment . . . ." (p. 15)

Result: The three experiments here reported show: (1) clear evidence of the effect of

vibration frequency on legibility and of interaction between frequency and other stimulus variables(, i.e.,) . . . (p. 17) (n)umerals (were) significantly less legible under high vibration frequencies than under low frequencies. . . (and t)he detrimental effect of high frequency vibration (became) more marked under unfavorable conditions of brightness, numeral size and amplitude . . .; (p. 1) (2) some indication, not statistically established, of an effect of circular versus linear vibration and corresponding interaction with other variables(, however the) . . . (p. 17) (p)attern of vibration was not significantly related to legibility(;) . . . (3) . . . (l)egibility was poorer for high amplitude vibration than for low. . . (this finding was consistent with previous results; and) . . . (p. 2) (4) no indication of a differential effect of black on white versus white on black under the conditions studied. . . (p. 17) (which) finding is contrary to earlier reports in the literature that black-on-white is superior." (p. 2)

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3301 Crook-1950a

Crook, Mason N., Harker, George S.,
Hoffman, Arthur C., and Kennedy, John L.
Tufts Coll., Medford, Mass.
EFFECT OF AMPLITUDE OF APPARENT VIBRATION, BRIGHTNESS, AND TYPE SIZE ON NUMERAL READING
AF Technical rept. no. 6246, Sep 50, 54p., 14 refs.
Contract W33-038 ac-14559
ATI-92 222

Problem: Determine the effect of brightness, type size, apparent vibration, and interactions between them on the legibility of black on white, "dial type," numerals in a MODERN type face.

Procedure: Nine exploratory, three main, and two supplementary experiments were run. The exploratory experiments showed a quite conclusive difference between the legibility results of single and multiple decrements. For example, "any one of the three factors (brightness, type size, and vibration amplitude could) be varied over a considerable range, when all other conditions (were) favorable, with no substantial impairment of performance . . .. But the value of such conclusions about the effect of variables in isolation is limited by the fact that secondary conditions are frequently not optimal. It is therefore important to consider interactions." (p. 20) The main experiments (numbers 10, 12, and 14) utilized 12 subjects each in a task that involved reading a three digit group, mentally adding the numerals, and comparing the result with a two digit group next to it. Response was by pushing one of two (correct or incorrect) response keys. All subjects had 20/25 or better visual binocular acuity. Reading distance was 14 inches. Auditory noise (from a motor driving prisms located between the eye and the stimulus) was present. Brightness of the reading material was controlled by metal film and cross-polarized filters. Vibration (in an elliptic pattern having a 3/2 major/minor axis ratio) was controlled by two counter-rotating pairs of disc prisms located two and four inches before the eye, and being driven at a constant 1050 cycles/second. The following variables (and their interactions) were utilized:

| experiment number | 10 | 12 | 14 |
|---|---|---|---|
| type size (points) | 6, 7, 8, & 10 | 6, 8, & 10 | 6, 8, & 10 |
| vibration (major axis displacement) (inches) | 0.006, 0.012, 0.018, and 0.030 | 0.00, 0.01, 0.02, and 0.03 | 0.0014, 0.0087, 0.0187, and 0.0291 |
| brightness (reading material) (foot-lamberts) | 15.2 | 1.00, 5.40, 10.10, and 15.10 | 0.010, 0.046, 0.21 and 0.94 |
| illumination level (subject field) (foot-lamberts) | ≅ 10 | ≅ 1.00 | none |
| test criteria | accuracy or speed | accuracy and speed | accuracy and/or speed |

Result: The following conclusions were drawn from the main experiments:

1. Performance was not significantly impaired by (a) decreasing brightness to 0.05 foot-lamberts, (b) decreasing type size to 6-point, or (c) increasing amplitude of vibration to 0.02 inches, if only one factor was varied at a time. In combination, the impairment in time and error scores was from 0 to 1100 percent.
2. For brightness, and possibly for type size, the range in which performance is not affected is broader for numerals than for "verbal material."
3. As a function of one variable (with other conditions favorable), performance "tends to improve rapidly to a critical value and then levels off sharply." (p. 26)
4. Impairment caused by the vibration induced here seems to be considerably less ("to judge from previous work"---p. 26) than would be caused by vibration of the head at the same amplitudes. However, "in some operational situations the visual vibration might be the more troublesome" (p. 27) because of "excessive amplitudes of relative movement." (p. 27) Some specific inferences are made about the tolerences to be found in "relative vibratory movement." (p. 27)
5. Experimental results here "should be considered as indicating the minimum impairments." (p. 26)

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2606 Crook-1951

Crook, Mason N. and Baxter, Frances Schulze

Tufts Coll., Medford, Mass.

RECOGNITION TIME FOR DIAL-TYPE NUMERALS AS A FUNCTION OF SIZE AND BRIGHTNESS

AF Technical rept. no. 6465, Mar 51, 26p., 7 refs.

Contract W33-038 ac-14559

ATI-119 387

Problem: Determine the effect of low to very low brightness and variations in size on the recognition time of a set of "white dial type digits on a dark ground," (p. iii) when presented singly and in groups.

Crook-1951

Procedure: Four experiments, using 4-16 male subjects (visual acuity equal to or better than 20/25), tachistoscopically read dial-type, light-on-dark, numeric, AND characters. The characters were back-projected onto a ground glass screen and read from a distance of 28 inches. Autokinetic effects were compensated for in the high-contrast experiments (1-3) by "floodlighting" (at 5 X $10^{-6}$ foot-lamberts) selective portions of the background. Digit brightness was varied between 0.003 and 0.1 foot-lamberts. Digit height was varied between 0.12 and 0.90 inches. In the first (main) experiment, "digits were presented singly at maximum brightness contrast" (p. 1) (for each level of illumination). The following combinations of conditions were used:

| brightness (foot-lamberts) | character height (inches) |
|---|---|
| 0.003 | 0.36, 0.63, and 0.90 |
| 0.01 | 0.26, 0.36, and 0.46 |
| 0.03 | 0.14, 0.22, and 0.36 |
| 0.1 | 0.12, 0.18, and 0.24. |

In the second experiment, digits were presented both singly and flanked by 0 and 5. The following brightness and size conditions were used:

| character height (inches) | brightness (foot-lamberts) |
|---|---|
| 0.18 | 0.1 and 0.03 |
| 0.36 | 0.01 and 0.003. |

Subjects responded to all digits when grouped. In the third experiment, digits were grouped 0D5 and 5D0 as before; brightness was held constant at 0.03 foot-lamberts; and digit heights were 0.14, 0.18, 0.30, and 0.36 inches. Subjects were instructed to respond to the middle digit only. In the fourth experiment, with contrast reduced by "floodlighting" at 0.003 foot-lamberts, digits were presented singly and in groups at a constant brightness level of 0.03 foot-lamberts, thus providing an effective brightness of 0.033 foot-lamberts and a contrast ratio of 0.91. Digit heights used were 0.22, 0.29, and 0.36 inches. In the grouped presentation, subjects responded to the middle digit. Recognition time was measured in all experiments.

Result: The following conclusions were drawn:

1. Average recognition time for 0.48-inch-high digits, presented singly, at maximum contrast, and at a brightness level of 0.1 foot-lamberts, was 0.6 seconds. "Decreases in size or brightness from this level produce at first a gradual and then a more rapid increase in recognition time." (p. 25)
2. Where the effects of size and brightness were small, the effects of subject differences, digit grouping, and moderate brightness contrast reduction were also relatively small. When size and brightness produced large variables, the secondary effects were also significant, e.g. "unfavorable conditions impair(ed) the performance of the poorer . . . relatively more than . . . the better subjects." (p. 25)
3. The reported data suggested 0.7 seconds as a median recognition time cutoff point.

To permit recognition within this, a digit would have the following characteristics: 0.23-inch height at 0.1 foot-lamberts, 0.30 at 0.03, 0.44 at 0.01, and 0.64 at 0.003. Recognition by three-fourths of the group, using these same size/brightness parameters, would require a recognition time of 0.85 seconds. Thus, "size-brightness combinations below the cut-off point involve . . . digits that are too large . . ., or brightnesses too high . . . . Compromises are therefore necessary (in operational situations)." (p. 25)

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2603 Crook-1952

Crook, Mason N., Hanson, John A. and Wulfeck, Joseph W.
Tufts Coll., Medford, Mass.
THE LEGIBILITY OF TYPE AS A FUNCTION OF REFLECTANCE OF BACKGROUND UNDER LOW ILLUMINATION
WADC Technical rept. 52-85, Jun 52, 16p., 2 refs.
Contract W33-038 ac-14559
ATI-165 547

Problem: Determine the effect of illumination level, type size, background reflectance, and their interactions on the legibility of type, such as is normally used on aeronautical navigation charts, to be read under conditions of low, red, cockpit illumination.

Procedure: Twelve male students (19-30 years old, and having normal color vision and binocular acuity) performed a cross-out comparison reading task on a dark-on-light, alphabetic, medium width, upper- and lower-case, MONOTYPE GOTHIC type face at a minimum reading distance of 14 inches. Adaptation problems were provided for. Characteristics of the type were as follows: 6-point - letter height = 1.65 millimeters, loop height (height of lower-case letters lacking ascending or descending stems) = 1.2 millimeters, mean lower-case letter width = 0.89 loop height, stroke-width = 0.27 loop height, and mean letter spacing = 0.48 mean lower-case letter width; 8-point - all dimensions increased by a factor of 1.3. Experimental variables were as follows:

| | illumination levels (foot-candles of red light) | |
|---|---|---|
| reflectance | 6-point | 8-point |
| 0.26 | 0.043, 0.057, 0.075, 0.129 | 0.021, 0.037, 0.057, 0.102 |
| 0.49 | 0.021, 0.037, 0.057, 0.102 | 0.014, 0.028, 0.043, 0.070 |
| 0.87 | 0.014, 0.028, 0.043, 0.070 | 0.014, 0.021, 0.028, 0.051 |

Each subject was given each of the 24 combinations of variables once. Speed and accuracy were measured.

Result: "The legibility of 6- and 8-point GOTHIC lower case black print falls off at an accelerated rate as, (1) the level of red illumination is reduced from 0.129 to 0.014 FT-L (sic), and (2) reflectance of background is reduced from 0.87 to 0.26. The legibility is less in all cases for 6-point than for 8-point type." (p. 15)

3306 Crook-1954a

Crook, Mason N., Hanson, John A., and Weisz, Alexander
Tufts U., Medford, Mass.
LEGIBILITY OF TYPE AS DETERMINED BY THE COMBINED EFFECT OF TYPOGRAPHICAL VARIABLES AND REFLECTANCE OF BACKGROUND
WADC Technical rept. 53-441, Mar 54, 24p.
Contracts W33-038 ac-14559 and AF33(616)-2018
AD-43 309

Problem: Determine the effect of letter height, stroke-width, letter spacing, background reflectance, and their interactions on a "regular" width, upper case, EXPERIMENTAL type face under conditions simulating low level, red, cockpit illumination.

Procedure: After three preliminary experiments that were performed "to give some evidence on interactions involving background reflectance and (type) size ."... (p. 3), the main experiment was an oral reading task using 12 male subjects that had normal color vision and binocular acuity. Stimuli were black, experimental (simulated GOTHIC, based on VARIGRAPH template VB-UN, with mean letter height equal to 0.064 inches), alphabetic characters under the following conditions (combined factorially to provide 54 interactions):

1. Mean letter width was set at 86.3 percent of letter height, which is in the range of "regular" letter widths.
2. Illumination level was set at 0.082 foot-candles (red).
3. Letter height was varied by changing viewing distance and hence visual angle. This created equivalent letter heights of 0.045, 0.064, and 0.090, which approximated 4, 6, and 8-1/2 points respectively.
4. Stroke-width averaged 9.8 percent (light), 21.1 percent (intermediate), and 30.0 percent (bold) of letter height.
5. Letter spacing averaged 35.6 percent (medium) and 63.2 percent (wide) of letter height.
6. Copy was printed on papers (quality, finish, and color differences not distinguishable under illumination conditions used) with red light reflectances (contrast?) of 87, 49, and 26 percent.

Speed and accuracy were measured.

Result: For the conditions stated, i.e. upper case, "regular" width, GOTHIC alphabetic characters under low level red illumination, the following generalizations were derived from the statistical evaluation:

1. "No advantage . . . (was) gained by increasing letter spacing beyond 50 (percent) of mean letter width (sic)." (p. 16)
2. Optimum stroke width was approximately "22 (percent) of mean letter width" (sic!) (p. 16) with large type and high contrast, but was not critical for these conditions. As contrast decreased, the optimum stroke-width shifted to 25 percent and became more critical. Also, as other variables deteriorated, increasing stroke-width over optimum had less degrading effect on legibility than decreasing the stroke-width under optimum with the same deterioration in other variables.
3. For letters of at least 0.064 inches height, with optimum stroke-width and spacing, a reduction in background reflectance to 50 percent had little effect on legibility. For less favorable conditions, reducing reflectance impaired legibility at any level.
4. As letter size was increased, legibility increased at a decelerating rate, particularly as other conditions became more favorable.
5. Limited data from the three preliminary experiments indicated that the effects of variables used on lower case were consistent with the effects on capitals when allowances were made for differences in basic letter size.

A rather detailed discussion of the results is given. This includes specific interpretations

of the data on spacing, stroke-width, reflectance, type size, lower case measurement variants, and other miscellaneous information.

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2604 Crook-1954b

Crook, Mason N., Hanson, John A. and Weisz, Alexander
Tufts Coll., Medford, Mass.
LEGIBILITY OF TYPE AS A FUNCTION OF STROKE WIDTH, LETTER WIDTH, AND LETTER SPACING UNDER LOW ILLUMINATION
WADC Technical rept. 53-440, Mar 54, 34p., 5 refs.
Contracts W33-038 ac-14559 and AF 33(616)-2018
AD-56 537

Problem: Determine the effect of letter width, stroke-width, letter spacing, and their interactions on the legibility of small, upper- and lower-case, EXPERIMENTAL type faces under conditions of high and low illumination, with a view to improving type design and letter spacing on aeronautical charts that are to be read under conditions of red cockpit illumination.

Procedure: Two major and several small supplemental experiments were run. In each of the two major experiments, 18 male subjects having normal color vision and binocular acuity read six-point (approximately), black-on-white, experimental (simulated GOTHIC), alphabetic characters under the following conditions: experiment one (comparison test) - lower case [based on VARIGRAPH template EV-ULN, and with mean loop height (height of lower-case letters lacking ascending or descending stems) = 0.046 inches] in three stroke widths, two letter widths, and three letter spacings; experiment two (oral reading) - upper case (based on VARIGRAPH template VB-UN, and with mean letter height = 0.064 inches) in the same number and type of variables as for experiment one.

| | | | stroke-widths | |
|---|---|---|---|---|
| letter widths | | (light) | (intermediate) | (bold) |
| (regular) | 90.3/86.3 | 22.0/11.4 | 29.6/24.6 | 34.4/34.7 |
| (condensed) | 71.3/59.8 | 18.9/14.6 | 26.3/25.9 | 28.6/34.4 |
| | | | letter spacing | |
| | | (close) | (medium) | (wide) |
| (regular) | 90.3/86.3 | 14.3/8.1 | 54.7/35.6 | 95.4/63.2 |
| (condensed) | 71.3/59.8 | 9.1/4.8 | 35.7/25.4 | 62.3/46.1 |

figures to left of virgule (/) are mean percentages of lower-case loop height for experiment one
figures to right of virgule are mean percentages of upper-case letter height for experiment two

Factorially combining the variables with two conditions of illumination (0.08-0.09 foot-candles red and 13.6 foot-candles white light) provided 36 combinations of variables and

interactions in each experiment. Visual adaptation problems were minimized. Speed and accuracy were measured.

Result: While the report details a large number of typographical design suggestions, the following generalizations (derived from the experiments) seem pertinent to low illumination effects:

1. Type characteristics affected legibility more markedly under low illumination.
2. Capitals were read more easily than lower case.
3. Both upper and lower case were read more easily in "regular" vs. "condensed" widths. Under high illumination, "regular" letters held only a slight advantage.
4. With the exception of material set in close spacing, a stroke-width approximately equal to "25 (percent) of mean letter width" (sic) (p. 26) is optimum for both upper and lower case in both "regular" and "condensed" widths. Under high illumination, stroke-width effect is small, but similar in pattern to the effect under low illumination.
5. Mean letter spacing approximately equal to "50 (percent) of mean letter width" (sic!) was optimal under low and high illumination.
6. Interactions occurred among the two design and one spacing factors, with the single most unfavorable combination being narrow stroked, closely spaced, condensed letters.

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2607 Crook-1954c

Crook, Mason N. and Baxter, Frances Schulze
Tufts Coll., Medford, Mass.
THE DESIGN OF DIGITS
WADC Technical rept. 54-262, Jun 54, 65p., 47 refs.
Contract W33-038 ac-14559
AD-50 080

Problem: Determine the effect of the following variables on the legibility of luminous digits of very low brightness: width to height ratio (with area both constant and variable), stroke-width to height ratio, spacing, configuration, defective strokes, inter-digit confusion, experimental method, and some interactions between these. Compare the results with the results of previous experiments with a view to improving the design of low level, transilluminated, dial type numerals.

Procedure: In an extensive series of recognition (with verbal response) tasks, 4-16 male subjects (having 20/25 or better visual acuity) tachistoscopically read back-projected, light on dark, AND numeric characters singly and in groups, under low illumination, and at a viewing distance of 28 inches. Illumination of the digits was 0.011-0.017 foot-lamberts. Subject adaptation was accounted for. Illumination of the field was 5 X $10^{-6}$

foot-lamberts floodlighting (sic). Using a standard of 0.19 inches, character height was varied between 0.095 and 0.38 inches. Different numbers were used for different tasks. Digit widths used were standard, 10 percent wider, and 10 percent narrower. Height to width ratios (in a constant area task) and their corresponding height to stroke-width ratios were as follows (widths and stroke-widths expressed as a percentage of height):

| | | | | | | |
|---|---|---|---|---|---|---|
| width | = | 50 | 57 | 67 | 80 | 100 |
| stroke-width | = | 10.8 | 11.5 | 12.5 | 13.7 | 15.3. |

When width to height ratio was held constant, the following stroke-width values were used (percentage of height for both):

| width | stroke-width | | | |
|---|---|---|---|---|
| 67 | 11.2, | 12.5, | 13.7, and | 16.1 |
| 50 | 8.3, | 10.6, and | 12.7. | |

Digit spacing used was 5.4 and 16.2 percent of height. Configurational changes were experimented with, as for example, changing the flat upper horizontal stroke of the "3" to a rounded curve. Defective strokes were tested by removing, one at a time, each of eight (sic) strokes in each digit. Inter-digit confusion was tested by placing numbers in groups and testing for selected members. Rank order of recognizibility was discussed in light of a previous experiment. Test criteria were varied in several experiments between "size threshold," "recognition time," and "error score." An extensive review of and comparison with the work of other investigators was made.

Result: The following general conclusions were drawn from the experiments:

1. Overall digit size (area) is important and must be considered in comparing different designs. Within a constant area, height-to-width ratio changes have effects that vary from digit to digit.
2. "It is easier . . . to measure the effect of dimensional . . . than configurational changes." (p. 52)
3. "Very narrow stroke-widths and . . . -digit spacing are disadvantageous." (p. 52)
4. A round top was more legible than a flat top "3".
5. Inter-digit confusions were most troublesome in the combinations 3-5, 4-6, 0-6, 5-6, and 0-9. With the defective stroke presentation, the result showed consistencies that may be of value in design.
6. Rank order of "recognizability" for the AND digits (from previous experiments) was (best to worst) 7, 9, 2, 5, 3, 1, 6, 4, 8, and 0.
7. Perceptual phenomena, individual subject performance, and experimental procedure all influenced digit recognition.

In a rather extensive literature review correlations were made with previous work in which experiments utilized the following digit sets (identified as): AMEL, AND, BERGER (black on white), CRAIK, EXPERIMENTAL, LEROY, MACKWORTH, OPEN, ORDNANCE, and ROUND. Conclusions made in this context were as follows:

1. Many variables of digit design, experimental procedure, and interactions involving both of these may affect digit legibility.
2. Stroke-width data from different investigators show superficial contradictions, but

"a general trend in the direction of an increase in optimum strokes as brightness decreases." (p. 52) Considering the effects of contrast amount and direction, and exposure time, "most of the contradictions can be resolved and . . . fitted into a coherent pattern." (p. 52)

3. Comparative tests have usually involved digit style or experimental procedure modifications. It is necessary to take these into account.
4. In dial-type numerals, AMEL has been best validated, but specifically for use on aircraft control panels.

The paper also defines four levels of design modification. These are as follows:

1. "Changes of detail resulting in only minor departures from some current design." (p. 1)
2. "Substantial innovations, which might or might not show a regard for aesthetic considerations and printing conventions, but which retain the essential features of traditional patterns." (p. 1)
3. "Radical innovations which constitute departures from existing patterns, but which have enough familiar elements to be correctly recognized at first glance or with a minimum of learning." (p. 1)
4. "Entirely new patterns, which could probably be made more discriminable than those now in use, but which would create a problem of relearning and habituation." (p. 2)

* * *

3295 Crook-1959
Crook, Mason N.
Tufts U., Medford, Mass.
THE EFFECT OF NOISE ON THE PERCEPTION OF FORMS
IN ELECTROVISUAL DISPLAY SYSTEMS
Final rept., 31 Jan 59, 15p., 15 refs.
Contract DA-49-007-MD-536
AD-218 902

Problem: Determine "the effect of visual noise on the perception of familiar and unfamiliar forms against plain and complex backgrounds in a prototype electro-visual system." (p. i)

Procedure: In several experiments, 6-18 subjects viewed, and were required to recognize and/or compare, dark on light (primarily), experimental, silhouette forms in a 52 line per (vertical) inch, experimental, electro-visual, facsimile system. The forms were both familiar and irregular and were presented on both simple and complex backgrounds. Illumination was at 0.28, 2.56, and 30.60 foot-candles. Varying types and amounts of visual noise degradation were present. "Landolt rings . . . provided a convenient scale by which two types of degradation (size of detail and what detail) could be compared." (p. 9) Area, perimeter, geometric construction, and familiarity of objects were the primary criteria for form construction. Test criteria were accuracy, or accuracy and speed.

Result: Experimental results included the following specific findings:

1. Display system characteristics - "Recognition increased with increasing signal/noise ratio for all the materials tested . . . (H)igher definition (more printing elements in a form of standard size) produced substantially better

recognition under noise. . . (There was) a much more rapid change in recognition scores when both contrast and contour impairment were operating than when contrast alone was varied. It is clear that different types of degradation do not necessarily produce equivalent results. . . For the simpler and more recognizable patterns, scores improved with increasing illumination from 0.28 to 2.56 foot-candles, but not beyond . . . ." (p. 5-6)

2. Form characteristics - "Perimeter, area, and the ratio of perimeter to square root of area were determined . . . (but c)orrelations were not computed because inspection . . . indicated that all coefficients would be either approximately zero or very low . . . Results . . . indicate(d) that the response tendencies for the four-sided forms . . . were different (not necessarily better or easier) from those for the more complex categories. . . (I)t appeared that the specific requirements of the task determined whether scores would differ as a function of form complexity. . . The recognition-noise functions for the irregular (and 'difficult') forms . . . indicat(ed) less precision in the judgments. . . Whether the forms were shown in their natural contrast relation or the reverse was found to have no effect on recognizability. The data provided some indication, however, that copy printed dark on light was more recognizable than the reverse, regardless of the type of object represented." (p. 6-8)
3. Complex backgrounds - "The main effect of complex backgrounds was to disrupt form contours with resulting impairment of recognition scores." (p. 9)
4. Interactions - "Various interactions were manifest among form characteristics, definition, noise level, and background condition. . . They cannot readily be itemized." (p. 9)
5. A scaling device - "(O)nce the recognition threshold for a particular form (was) established in terms of noise level, Landolt rings provide(d) a means for determining the size of detail which (was) just discriminable at that level, . . . inferring what detail of the form (was) most critical." (p. 9)
6. Subjects' response patterns - "(A)ttitudes and assumptions, often unconscious, inevitably come into play in operational situations, and eventually undergo whatever adjustment processes the practical requirements make necessary. For more precise control and prediction, . . . an understanding of the psychological processes as well as the average performance levels is much to be desired." (p. 10)
7. Familiarity - "(I)ncreased familiarity did not improve the same-different judgments on noisy copy. (It should not be inferred that the same result would hold for an absolute identification task.) The several different familiarization procedures used were found to differ, not primarily in overall effectiveness, but in effectiveness for particular types of discrimination, . . . the implication (being) . . . that generalizations are hazardous unless based on an understanding of the psychological processes involved." (p. 11-12)

The following broad conclusions were drawn:

1. Recognition loss resulting from visual noise degradation in the system used presented "difficult, but not prohibitive, technical problems." (p. 13)
2. Recognition in the system was limited by resolution, amount of noise, indefineable form characteristics, background detail, interactions among these, and the subject's interpretation of the experimental situation. Tentative interpretations were presented for interactions among these limitations.
3. "Analysis of the objective variables needs to be supplemented . . . for a full understanding of form discrimination in complex displays." (p. 13)

* * *

2575 Crumley-1961

Crumley, Lloyd, Divany, Richard, Gates, Stephen,
Hostetter, Robert and Hurst, Paul
HRB-Singer, Inc., State College, Pa.
DISPLAY PROBLEMS IN AEROSPACE SURVEILLANCE SYSTEMS.
PART I. A SURVEY OF DISPLAY HARDWARE AND ANALYSIS
OF RELEVANT PSYCHOLOGICAL VARIABLES
Rept. no. 256-R-2, pt. 1, 30 Jun 61, 257 p., 348 refs.
Contract AF 19(604)7368
ESD TR-61-33; AD-263 543

Extract: "This report describes . . . work . . . which has as its over-all objective the determination of the information presentation requirements of human data processing roles in future air and aerospace surveillance systems. . . Display parameters and operator characteristics . . . relevant to display selection . . . (,) reviews of some of the pertinent literature . . . (, and t)he description and specification of operator roles (are) . . . included . . . (p. vii) This report is (intended as) a working vehicle with information and reference data intended to support the conclusions and recommendations . . . in the final (classified) report." (p. ix) Thus, "specific implications of the factors studied are not delineated . . . (p. 2)

"Chapter I begins with a general discussion of surveillance systems and proceeds to a general discussion of displays, pointing up the information transfer interface problem in the design of displays for a given system. Finally, the approach used is described and discussed relative to the problems involved.

"Chapter II defines and discusses the display parameters which are important in the evaluation and selection of displays. In addition to important physical display factors (resolution, scale factor, transformation and accuracy, size, brightness, color, and shape), information factors (capacity load and speed, deliberate and incidental redundancy, reliability---signal/noise and isomorphism, replacement, and selectivity), and the temporal factors (currentness in parallel and serial presentation and interaction effects, initiation and termination factors of duration, and access time), a discussion of some of the pertinent display environment considerations is presented (temperature and humidity, light, and noise and vibration).

"Chapter III discusses operator characteristics, some of which will operationally dictate the inclusions or exclusions of certain display characteristics. Some of these will also define the limits within which certain display parameters can vary and still continue to produce efficient information flow through the operator.

"Chapter IV presents a functional analysis of the operator roles in the conceptual model . . . . This analysis is on a 'block by block' basis in relation to the conceptual model. It is from these functions that the operator roles will be developed and related to display selection in the final report . . . .

"Chapter V presents a digest of the state of the art in displays (see outline shown below).

Included are cathode ray tubes, character generating displays, projection techniques, trend recording techniques, photographic techniques, and three-dimensional displays. Display recommendations to be made in the final report will be drawn primarily from this discussion. . .

"Chapters VI, VII, and VIII are in essence parallel and supporting chapters to Chapter II. . . (They) point out in greater detail the influences of display parameters (see excerpts shown below), information processing factors, and ambient conditions upon operator performance. . . (M)any of the same factors are considered in . . . Chapter III . . .

"Appendix A is a functional description of what seems to occur when people 'process' information. If focuses upon the identification and ordering of the information processing stages." (p. 1-2)

An outline of the contents of Chapter V, the state-of-the-art in displays, is as follows:

- A. Introduction.
- B. Information requirements.
  - 1. Surveillance systems.
  - 2. Real-time displays.
  - 3. Semi-static, second order information.
  - 4. Predictive type information.
  - 5. Historical information.
- C. Cathode-ray tubes.
  - 1. Advantages and disadvantages.
    - a. Phosphor screens.
    - b. Flicker.
    - c. Frequency response problem.
    - d. Auxiliary storage.
    - e. Storage tube auxiliary system.
    - f. Information quantity.
    - g. Use of color.
    - h. Auxiliary methods.
  - 2. New developments in cathode-ray tubes.
    - a. Storage tubes.
      - (1). General discussion.
      - (2). Illustrative examples.
        - (a). TONOTRON (Hughes Aircraft Company).
        - (b). MEMOTRON (Hughes Aircraft Company).
        - (c). Westinghouse.
    - b. Thin cathode-ray tubes.
      - (1). AIKEN tube (W. R. Aiken).
      - (2). Image-intensifier tube.
    - c. Fiber-optic cathode-ray tube.
- D. Character generation.
  - 1. General discussion.

2. Cathode-ray tube character display schemes.
    a. Beam-shaping.
        (1). CHARACTRON (Stromberg-Carlson).
        (2). INDICODER (Stromberg-Carlson).
        (3). COMPOSITRON (Radio Corporation of America).
    b. Handwritten or stroke method.
        (1). ALPHADYNE character generator (Skiatron Electronics and Television Corp.).
        (2). Harmonic character generator.
    c. Scanning or raster method.
        (1). VIDEOGRAPH character generator (A. B. Dick Co.).
        (2). VIDIAC (CBS Laboratories).
    d. Dot pattern system.
        (1). DOTITRON (Link Division, General Precision, Inc.).
3. Individual alphanumeric units (electromechanical, electromagnetic, electro-optical, and electronic).
    a. Industrial Electronic Engineer indicator (Industrial Electronic Engineers).
    b. UNION indicator (Union Switch and Signal Division, Westinghouse Air Brake Company).
    c. Teleregister digital indicator.
    d. NIXIE tube (Burroughs Corp.).
4. Field emission displays.
    a. Electroluminescent displays.
        (1). Theory of electroluminescence.
            (a). Input requirements.
            (b). Cell life and humidity.
            (c). Colors.
            (d). Color versus frequency.
            (e). Advantages as display devices.
        (2). Electroluminescent alphanumeric displays.
        (3). Electroluminescent plotter-type displays.
        (4). Electroluminescent translator-display devices.
        (5). Electroluminescence and photography.
        (6). Electroluminescent-ferroelectric display.
        (7). Electroluminescent-piezoelectric display.
    b. Liquid matrix-cell displays.
    c. Gaseous matrix-cell displays.
5. Hard-copy printers.
    a. XEROGRAPHY printer (Stromberg-Carlson).
    b. VIDEOGRAPH printing (A. B. Dick Co.).

E. Projection techniques.
1. EIDOPHOR.

2. Thermoplastic recording (General Electric Company).
3. Light Valve Projector (General Electric Company).

F. Trend recorders.

1. Electro-Plotter (Benson-Lehner).
2. Light Beam Plotter (Sanborn Company).
3. Optical Plotter (Fenske, Fedrick, and Miller, Inc.).

G. Photographic techniques.

1. Conventional projection techniques.
2. KALFAX photography.
3. Rapid-development techniques.
4. Kelvin-Hughes projection system.
5. Ramo-Wooldridge Color Display System.

H. Third-dimension display.

1. Methods for presenting the third dimension (three-dimensional models; two-dimensional representation of a three-dimensional occurrence such as isometric or perspective drawings, or stereoscopic devices; coding techniques such as representing the third dimension by color coding, alphanumeric character, or separate digital indicator; etc.).

Specific excerpts from Chapter VI which seem to be of interest here are as follows:

1. Resolution - "Under good viewing conditions, the eye is capable of resolving detail which subtends a visual angle of less than one minute of arc. . . (p. 140) (T)here are . . . two kinds of resolution: 'real' . . . and 'apparent' . . . (R)esolution from the standpoint of the operator . . . is 'apparent' or visual resolution. . . The human visual apparatus tends to reshape gradients of light to produce apparent sharp contours. . . (V)isual resolution . . . cannot be predicted, in a simple way, from facts known about the .". . (p. 141) "real" resolution. Thus, "resolution must be judged relative to the use to which the display is going to be put. Cost factors and information overloading factors are important considerations here." (p. 142) For this, "(i)t would be extremely helpful to develop operational ranges of required resolution for a number of generalizable operator tasks." (p. 142) In addition, it is noted that "(m)any other factors such as ambient illumination, scale factor, brightness contrast, etc., interact with resolution in evaluating this factor from an operator standpoint." (p. 140)
2. Scale factor and display size - "It is generally agreed that an object of complex form must subtend a visual angle considerably greater than one minute of arc in order to be identified by its form. . . It has been estimated that a complex form must subtend at least 12 minutes of visual angle in order to be identified under favorable conditions, and that under operating conditions a figure of 20 minutes is not unreasonable." (p. 143)
3. Transformation and accuracy - "(T)here are essentially two kinds of distortion which can affect the transformation and accuracy of displayed information; these are purposeful and non-purposeful distortion. . . (P)urposeful distortion generally leads

to improvement of performance. Some examples (from a radar PPI display) . . . are time distortion, logarithmic or nonlinear range representation, scope sector 'blowups,' etc. . . Non-purposeful distortion can either be that which is inherent in the display equipment itself, or that which is caused by auxiliary equipment such as operator or display aids. In either case, the distortions are relatively minor . . . ." (p. 145) Various types of non-purposeful distortion are parallax from an overlay; flat-face, pincushion, rhombic, noise, and bandwidth distortion in cathode-ray tubes; and various other image distortions.

4. Brightness - "At high brightness levels, the eye is sensitive to brightness change of as little as 1 (percent), while at low . . . levels changes of 100 (percent) or more may not be discriminated. This immediately suggests . . . that visual discriminatio(n) of . . . display(s) . . . could . . . be optimized in terms of brightness. . . (D)etectability is impaired at low intensities by the characteristics of the eye, and at high intensities by the characteristics of the (display). . . (p. 146) Other important problems . . . are the retinal adaptation of the operator's eye, and the . . . ambient illumination . . . Brightness and illumination considerations for . . . wall maps, charts, printed materials, etc., are rather well known and (are) not . . . considered in any great detail . . . (T)he desirability of good diffusion and the elimination of glare spots and areas of high brightness contrast . . . are generally accepted and (are) not . . . elaborated (upon) . . . Luckiesh and Moss recommend increasing amounts of light for progressively finer or more difficult work up to a minimum of 100 foot-candles for very exacting work. Tinker . . . considers a maximum of 50 foot-candles to be adequate for the most exacting tasks. . . Illuminating engineers have tended to follow Luckiesh and Moss. . . Scale and dial reading speed both increase with increasing brightness. . . (F)or most . . . types of visual displays (possibly excepting radar) . . . increased precision requirement demands an increase in brightness." (p. 147-148)

5. Color - "(C)olor is a desirable coding feature . . . (T)he number of absolutely identifiable hues may range from 5 or 6 up to 16, depending upon the individual . . . . Under idealized viewing conditions, half of the observers . . . (should) discriminate without appreciable error nine maximally saturated colors. . . (U)nder . . . limited . . . viewing conditions, . . . eight surface colors appear to be the maximum . . . (F)ive, six, or seven, will probably be necessary for most practical purposes. . . (C)olor provides an additional dimension for the presentation . . . (S)elf-luminous colors, i.e., lights, excited phosphors, etc., can be utilized over a wid(e) range of ambient lighting conditions. . . (C)olor recognition requires little additional training . . . (T)he attention-getting value of color as a coding symbol is widely recognized. . . (S)ome people are color defective, in which case they cannot utilize the codes. . . Color discrimination is seriously degraded when surface colors . . . are viewed under highly chromatic light source(s) . . . The character and stability of . . . (the cathode-ray tube color) display is difficult to create and control. Color judgments are influenced by many aspects of the surrounding conditions. . .

(S)urface colors have a tendency to fade with age. . . (and) must be kept clean . . . . Electronically generated color symbols are subject to distortion and (colored) noise limits. . . (S)ignals or color patches of small dimensions, 20 (minutes) or less in visual angle, cause normal subjects to show certain characteristics of anomalous color vision. . . Devoe and Duva have described a method of display sharing through the projection of several different displays onto the same screen, and selecting the desired display by viewing it through an appropriately colored filter." (p. 148-150)

6. Shape - "The coding possibilities offered by Arabic letters (sic) and numerals are well known, and the legibility standards for these are well established. (sic) Therefore, we . . . deal mainly with . . . more unconventional coding. . . (S)pecial applications include . . .: (a) writing the symbol on a CRT by means of an electron beam, (b) maximum information per unit of display area, and (c) minimum interference with the readout of target position and the use of trail on a pictorial display. . . The basic unconventional code symbols are inclination, ellipse ratio, blip diameter, and color . . . (Twelve,) and if necessary as many as 16, categories of inclination can be employed even when a small amount of noise is expected on the display. . . By employing a complex symbol(, an) . . . alphabet (could) provid(e) up to 12 bits of information per symbol. All of these codes, except, perhaps, color are presently feasible for use with some CRT's or with an optical projection system. . . Another coding dimension which should be considered is one employing . . . arbitrary shapes . . . Simple symbols often have great mnemonic or associative value. . . In a situation such as air traffic control, the use of symbolically coded targets should give the controller a better picture of the total situation . . . (I)f the information requirements of a given task do, in fact, merit the use of complicated symbology, the general consensus of opinion seems to be that it will be worth the extra cost of the equipment in terms of the advantages gained." (p. 151-152)

* * *

2197 Dearborn-1906

Dearborn, Walter F.
THE PSYCHOLOGY OF READING, AN EXPERIMENTAL STUDY OF THE READING PAUSES AND MOVEMENTS OF THE EYE
Archives of Philosophy, Psychology and Scientific Methods, J. McKeen Cattell and Frederick J. E. Woodbridge, Editors, No. 4, March 1906
Columbia U. Contributions to Philosophy and Psychology, Vol. 14, No. 1
New York, The Science Press, 134 p.

Problem: "(D)etermine . . . the form and character of the movement of the eye in reading, and . . . define or plot the positions on the page which correspond to the so-called fixation or reading pauses of the eye." (p. 8)

Procedure: "(Q)uestions . . . concerning the perception and recognition of words and sentences, the typographical and more purely physiological factors which impede or aid in reading, the basis of the individual differences in the rapidity of reading and other related problems (are) discussed in reference to the data . . . obtained." (p. 8) The following outline of contents indicates the scope and coverage of this monograph:

I. Introduction.

II. Historical summary.

III. Methods and records (including (a) methods and apparatus, (b) explanation of records and the method of measurement, and (c) description of accompanying photographs).

IV. The fixation pauses (including (a) the number of fixation pauses and the extent of page read per fixation, (b) motor habits, and (c) refixations).

V. Is there perception during eye movement?

VI. The distribution of attention in perception.

VII. Visual processes involved in recollecting.

VIII. The duration of the fixation pauses (including (a) relation to the number of pauses, and (b) the length of fixation and the reaction time of the eye).

IX. The span of attention and the duration of pauses (including experimental isolation of the reading pauses).

X. The number span of attention.

XI. The location of the fixation pauses (including (a) the location of pauses in ordinary reading; (b) proof reading, effect of articulation, etc.; (c) children's reading; and (d) the effect of long and short words).

XII. The length of text lines and motor habits.

XIII. Rapidity of reading.

XIV. The fatigue of the eyes in reading.

XV. Summary and conclusions.

Appendix. Passages used for experimentation (excerpts only, but excluding the typewritten nonsense word and number groups).

Regarding "III", above, the apparatus used was a modification of the Dodge falling plate camera, which photographs movements of the corneal reflection. The apparatus and method described were thought to be especially useful in prospective work with children.

Result: The following selected excerpts are applicable to problems of readability: The author's "relation of fixation and attention is at variance with the Wundtian theory, developed by Zeitler. . ." (p. 49) who would have the subject fixate on "the so-called domineering letters. . . (as) the principal basis for perception. (Domineering letters are (1) capitals, (2) letters that stand above the line as l, t, d, h, k, and especially such combinations as scht, and (3) in some instances m, w; i.e., the broader letters . . .) Messmer's . . . statement" (p. 49-50) compared this theory with the concept that "the more the letters of slight individual form (with straight lines) predominate, so much the greater is the impulse to a unitary (perception)." (p. 50) In addition, "(t)here is . . . evidence to support the observation that the threshold of perception of the domineering letters . . . is lower than that of the other(s) . . . (The following letters were . . . perceived apart . . . (as) found in Messmer's tables: i, k, h, w, g, . . . b, gew, sch, her, ge, . . . d, . . . ch, . . . S, nnen)." (p. 52) Messmer contends that "every other partial perception of a word is by syllables" (p. 52) and that h, t, fl, etc., are not dominant letters. In considering dominant letters, Erdmann and Dodge stated that "'words of characteristic optical "Gesammtform" are more easily recognized than those of undifferentiated (gleichförmiger) configuration.'" (p. 53) Cattell found the dominant letters, i.e., "the letters most easily perceived, mainly 'those letters which project above the body of the word and the additional middle sized letters x and z.'" (p. 90) The author hypothesizes that the dominant letters "furnish . . . a better form of peripheral stimulation . . ., i.e. they 'catch the eye' more readily." (p. 90)

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3346 Dearborn-1951

Dearborn, Walter F., Johnston, Philip W.
and Carmichael, Leonard
Tufts U., Medford, Mass.
IMPROVING THE READABILITY OF TYPEWRITTEN
MANUSCRIPTS
Proceedings of the National Academy of Sciences,
37:10 (October 1951) 670-672, 2 refs.

Problem: Determine a manner in which "a typewritten page may be prepared which is not displeasing in appearance to most readers and which significantly increases the comprehension of the material presented." (p. 672)

Procedure: After preliminary selection (based on "good experimental (and/)or theoretical justification"), (p. 670) a "peak stress" typewritten format was adopted for major experimentation. The article describes only this final format and experiments performed with it. In this "peak stress" format, "explicit indication of the author's meaning is given by capitalizing (. . . italics . . . might be preferable) in each sentence that word to which the author would give maximum oral stress. . . Other changes . . . worthy of mention are (1) a two-column arrangement . . .; (2) single-spaced lines . . .; (3) other 'spatial' arrangements which break up the article for the reader into more comprehensible units of thought and; (sic) (4) the blackening of certain sections (effected by retyping over the original) deemed by the author to be of particular importance." (p. 671) The first experiment involved 70 college students, who "were required to read (individually) a long

article of moderate to severe difficulty in conventional format and in peak stress format. The design of the experiment was . . . altered for group experimentation. . . This basic experiment was subsequently repeated four times. In these . . ., new sets of college subjects were first given two standardized tests of reading (the Nelson Denny and the California Advanced Reading Test) and were then 'paired' on the basis of the averages of their scores in these two tests. One of each pair read the materials in the peak stress form and the other in the conventional format. Four groups of approximately twenty students each were thus examined." (p. 671) Subsequent to these tests, a "demonstration of the efficiency of (the) new format was . . . made in a class of 38 graduate students at Harvard. In this case 85 words were deleted from both the new and the standard formats (the same words from each). . . (S)tudents . . . were . . . asked to read the article and to fill in the missing words." (p. 671)

Result: The results of the basic experiment showed "an increase in comprehension of 16 per cent over material presented in conventional typed format. The improvement . . . (was) significant at the five per cent . . . level." (p. 671) Also, "(t)he (new) format was definitely preferred---subjectively---by 95 per cent of these subjects." (p. 671) In the four subsequent experiments, "(t)he percentage gains of the subjects who read the improved format were for Experiment I, 22 per cent; for Experiment II, 30 per cent; for Experiment III, 10 per cent; and for Experiment IV, 18 per cent. The average gain for the half of the total population which (sic) read the new format was 19.5 per cent." (p. 671) In the Harvard demonstration, "(t)he readers of the new format succeeded in filling in 21 per cent more of deleted words . . . than did the readers of the conventional format." (p. 672) Further experimentation on the new format will utilize the electrical recording of eye movements.

* * *

2577 Decker-1961

Decker, James D.
Virginia Council of Highway Investigation and
Research, Charlottesville
HIGHWAY SIGN STUDIES -- VIRGINIA 1960
In PROCEEDINGS OF THE FORTIETH ANNUAL MEETING, 1961,
Herbert P. Orland, Editor (Washington, D. C.,
National Academy of Sciences-National Research
Council Publication 863, 1961), Vol. 40, p. 593-609, 5 refs.

Problem: "(C)ompare the (day and night, dynamic) legibility of two signs (placed to simulate a rural situation on the Interstate System of highways) having different color combinations but the same letter size and series." (p. 593) In another, unrelated, study, "investigat(e) the (day and night) visibility of various designs (stripe width, over-all size,

and color combination variables) for diagonally striped signs which are used as (bridge end) hazard warning markers on . . . highways." (p. 593)

Procedure: (Phase I---Legibility Study of Roadside Signs) "Twenty-four subjects (fourteen male and ten female, ranging in age from 18 to 38 years, and with visual far acuities ranging from 20/14 to 20/50, with a mean acuity of 20/20.3, and having normal color vision, each) read (12 pairs of signs) . . . (from) a moving vehicle (20 miles per hour) under three levels of illumination (daylight, and high-beam---four lamps, 150 watts ---and low-beam---two lamps, 100 watts---at night). . . in a simulated rural Interstate situation." (p. 594) On each sign were two-word messages. "The test words . . . all were four-letter(s) . . . so that they could not be identified by length alone. . . (p. 596) The twelve words chosen (familiar, but not necessarily those encountered on a highway) were: DOFF, DUDE, ELMS, FELT, FOOT, FUSE, LOOM, MODE, MULE, SELF, SIDE, (and) TOLL. . . The letters were all standard (U.S. Bureau of Public Roads) 'D' series upper-case, 10-(inch) high with a stroke width of 1-9/16 (inches). The words had a length expansion of approximately 10 to 15 percent over standard 'D' series spacing. The spacing used was that . . . designed for 10-(inch) upper case letters of a 'modified E' series." (p. 597) Color combinations used were (1) green non-reflectorized letters on a white (specified as silver) reflectorized field (this combination is effectively black on white at night), and (2) white reflectorized letters on a blue reflectorized field. "The (reflective field) sheeting was . . . made with a flat surface and a non-exposed lens system. . . (p. 595) (I)dentical words and spacings were used for both color combinations. . . The message panels (words) were (randomly) presented . . . two at a time, one above the other . . . ." (p. 597) The signs were posted with the "bottom edge 7 (feet) above the edge of the pavement and (the) roadside edge 17 (feet) from the edge of the pavement. . . (p. 595) (T)he sign faces formed an angle of somewhat more than 90 (degrees) with the edge of the pavement to prevent specular glare. . . (p. 596) (and were) placed . . . facing westbound traffic. . . (T)he daylight tests were conducted in the morning hours when the weather was clear. . . (p. 597) Traffic was kept out of the (test) section during night test observations to prevent opposing headlight glare and headlamp illumination from other cars on the sign face. . . (p. 598) The (legibility) distance was marked down . . . when (the subject) called aloud the second word. . . The data were initially subjected to an analysis of variance." (p. 600) Since "(t)he experimental design was a 3 (by) 2 factorial with two replications. . . (,) (p. 600) (t)he three sources of variation analyzed were the color combination, the level of illumination, and the interaction of these two factors." (p. 601)

Result: (Phase I---Legibility Study of Roadside Signs) Mean legibility distances were as follows:

| | white-green signs | blue-white signs |
|---|---|---|
| day | 657 feet | 662 feet |
| night-high | 466 feet | 533 feet |
| night-low | 404 feet | 488 feet |

(above from p. 600)

An analysis of variance performed on the interaction between color and illumination "show(ed) that the interaction (was) not significant in this test. That is, the effect of color on mean legibility distances (did) not depend on the effect of illumination level and vice versa." (p. 601) However, a second analysis, measured by standard deviation, showed a significant difference (at the 5 percent level) for the following (better vs. worse):

1. daylight vs. night high-beam for both white-green and blue-white signs,
2. night high- vs. night low-beam for both white-green and blue-white signs, and
3. blue-white vs. white-green signs for both night high- and low-beam.

There was no significant difference (at the indicated level) between white-green and blue-white signs under daylight conditions.

Procedure: (Phase II---Visibility Study of Striped Signs) "The visibility tests were conducted (on 12 full-scale, diagonally---upper-right to lower-left---striped signs---one standard and eleven that included variations in stripe width, stripe color, and over-all sign size) from a vehicle parked 1000 (feet) from the test signs.". . (p. 602) using ten subjects who each were seated in the right front of the car, and who had far acuities ranging from 20/18 to 20/22 with normal color vision. Daylight conditions were as for Phase I. "At night only high beams (rated at 150 watts) were used . . . ." (p. 602) No traffic was permitted on the road during the observations. The sign "structure was directly in line with the vehicle and because of a horizontal curve the signs could be placed on the shoulder of the highway. . . (S)ign centers were located 4.2 (feet) above the ground. . . (T)he sign faces were at an angle somewhat more than 90 (degrees) with the tangent of the roadway to eliminate . . . specular glare . . . ." (p. 602) Test sign configurations were as follows:

| | | | |
|---|---|---|---|
| 1. 24 inches square 5-inch stripes | 4. 30 inches square 5-inch stripes | 7. 36 inches square 6-inch stripes | 10. 36 inches square 3-inch stripes |
| red transparent color on white reflectorized sheeting | | | |
| 2. 24 inches square 5-inch stripes | 5. 30 inches square 5-inch stripes | 8. 36 inches square 6-inch stripes | 11. 36 inches square 3-inch stripes |
| black opaque paint on yellow reflectorized sheeting | | | |
| 3. 24 inches square 5-inch stripes | 6. 30 inches square 5-inch stripes | 9. 36 inches square 6-inch stripes | 12. 36 inches square 3-inch stripes |
| black opaque paint on white reflectorized sheeting | | | |

(above from p. 604)

"The sheeting used was of the flat-top design, consisting of glass spheres embedded beneath a flat outer surface. . . (p. 603) The signs (in pairs) . . . were rotated into view of the subject for a 3-(second) interval (during which time the subject told his preference to a recorder)." (p. 602) Thus, "(t)he experiment consisted of a preference test that used the technique of paired comparisons. Each observer saw all 66 possible (combinations, not permutations of) pairs . . . both at day and at night." (p. 603)

Result: (Phase II---Visibility Study of Striped Signs) The author states that "(t)here are two primary aspects of the perception of a sign that require the designer's attention. Detection is the aspect of a sign that permits it to be visually separated from the background against which it is seen. This characteristic is aided by the size, color, brightness, and location . . . . Discrimination is the aspect of a sign that permits it to be differentiated from other objects in the field of view. Symbols, messages, color, and shape control this quality . . . . (P)oor detection can result from: (a) a relatively small area of high brightness material . . . splashed with road dirt, (b) a lack of color contrast with the surroundings, (and) (c) obscured placement . . . Poor discrimination is primarily due to . . . symbol design; (e.g.) at normal viewing distances the 3-(inch) black-white stripes (sign 12.) often appear to merge into a uniform gray color. (Thus, t)his study was to test design changes that might improve (the) discrimination quality." (p. 605) Besides, the standard black-white, yellow-black and red-white combinations were selected for study because "(i)t was thought that (they) . . . would help identify the sign as a warning . . . It was also thought that an increased stripe width might improve the discrimination value of the symbol and simultaneously improve its detection value. If sufficient improvement . . . could be attained . . ., it . . . might be possible to reduce the . . . over-all sign size, and thereby get a sufficiently effective sign at a lower cost." (p. 605) The results of this study showed the following:

1. "The markers bec(a)me more visible as the stripe width increase(d). This was true even (when) the over-all size of the sign (was) somewhat reduced. In these tests, the 6-(inch) stripes (nos. 7, 8, and 9) were most easily differentiated, but the 5-(inch) stripes on the 24-(inch square) panel (nos. 1, 2, and 3) were more visible than the 3-(inch) stripes on the 36-(inch square) panel (nos. 10, 11, and 12)." (p. 607)
2. "Among signs of the same color combination, the sign with the widest stripe (nos. 7, 8, and 9; for the groups 1, 4, 7, and 10; 2, 5, 8, and 11; and 3, 6, 9, and 12; respectively) was the most effective . . . ." (p. 608) Also, "a reduction of approximately 30 percent in over-all area produces some degree of effectiveness." (sic) (p. 608)
3. "For signs of the same over-all size and stripe width (groups 1-3, 4-6, 7-9, and 10-12) the black-white combination (nos. 3, 6, 9, and 12) is the most visible, followed closely by the black-yellow (nos. 2, 5, 8, and 11) signs. The use of red-white stripes is to be discouraged because this color combination is difficult to discriminate." (p. 608)

The following over-all ranking was seen for the twelve signs:

| test-sign numbers | | | | | configurations | | |
|---|---|---|---|---|---|---|---|
| rank | day | night | d + n | | color | stripe | size |
| 1 | 9 | 8-9 | 9 | . . . . . . . . . . . . . . . | B/W | 6-inch | 36-in. sq. |
| 2 | 8 | 8-9 | 8 | . . . . . . . . . . . . . . . | B/Y | 6-inch | 36-in. sq. |
| 3 | 6 | 6 | 6 | . . . . . . . . . . . . . . . | B/W | 5-inch | 30-in. sq. |
| 4 | 5 | 5 | 5 | . . . . . . . . . . . . . . . | B/Y | 5-inch | 30-in. sq. |
| 5 | 7 | 7 | 7 | . . . . . . . . . . . . . . . | R/W | 6-inch | 36-in. sq. |
| 6 | 3 | 3 | 3 | . . . . . . . . . . . . . . . | B/W | 5-inch | 24-in. sq. |
| 7 | 2 | 2 | 2 | . . . . . . . . . . . . . . . | B/Y | 5-inch | 24-in. sq. |
| 8 | 4 | 4 | 4 | . . . . . . . . . . . . . . . | R/W | 5-inch | 30-in. sq. |
| 9 | 1 | 1 | 1 | . . . . . . . . . . . . . . . | R/W | 5-inch | 24-in. sq. |
| 10 | 12 | 12 | 12 | . . . . . . . . . . . . . . . | B/W | 3-inch | 36-in. sq. |
| 11 | 11 | 11 | 11 | . . . . . . . . . . . . . . . | B/Y | 3-inch | 36-in. sq. |
| 12 | 10 | 10 | 10 | . . . . . . . . . . . . . . . | R/W | 3-inch | 36-in. sq. |

* * *

3341 Deuth-1953

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FINAL ENGINEERING REPORT ON INFOMAX

Covering period 14 Dec 50-31 Aug 53

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Contract AF 33(038)-17923

AD-33 597

Problem: "(S)tudy the relations and effects of (the following) parameters on legibility when the communication system (a system in which the units of information---26 alpha and 10 numeric characters---are composed of a number of elements which are transmitted as separate signals and recorded on paper for visual presentation) is perturbed by Gaussian noise, and in so far as possible to determine an optimum set of parameters:

1. "Communication parameters--such as signal-to-noise ratio, bandwidth, rate of transmission, dynamic range, detector circuits, etc.
2. "Typographical parameters--such as character shape, size, spacing, etc." (p. 3)

Procedure (general): "A facsimile transmitter and printer were adapted for the production of INFOMAX test copy by the addition of a noise generator. Subsequently a circuit was added to permit the use of synchronous detection. . . Equipment was constructed in which the legibility of INFOMAX copy could be tested under controlled conditions of illumination and reading distance." (p. 1) In addition to a detailed summary of the engineering experimental program, the following material was extracted from the summary of the psychological experimental program.

Procedure (feasibility experiments---matrix size, gray scale, and noise): "These experiments required subjects to read single letters, scrambled groups of letters, and

words. In all cases, letters were synthesized from square elements and were shown under various degrees of simulated noise degradation. . . introduced by elimination of letter elements, by addition of elements in the surrounding area, and by elimination and addition combined. Material was presented both in black and white and in a 'gray scale' consisting of four steps of brightness. Two matrix sizes were used, one being seven spaces vertically by five horizontally per letter block and the other 14 by 10." (p. 7)

Result (feasibility experiments): "(U)nder the conditions of the experiments, legibility was better in the 14 by 10 matrix size . . ., and . . . in the gray scale . . . ." (p. 7)

Procedure (preliminary experiment 1---letter case---the first of "(a) series of preliminary experiments . . . undertaken in order to answer a number of questions of experimental technique and to provide a framework for the planning of more formal experiments") (p. 7): "A small scale comparison was made between noise-degraded capital - lower case letters in the same type style and point size." (p. 8)

Result (preliminary experiment 1): "The capitals proved to be more legible under noise." (p. 8)

Procedure (preliminary experiment 2---stroke width): "Measurements were made of per cent of area in a 'letter block' covered by the letter strokes, for several stroke widths, for the purpose of providing a preliminary check on the information theory prediction that the optimum would be 50 per cent." (p. 8)

Result (preliminary experiment 2): "Examination of noisy copy prepared from printed originals . . . indicated that under noise degradation, the most legible stroke width is that in which the strokes cover, on the average, approximately half the area of the rectangle circumscribing the widest letter." (p. 8)

Procedure (preliminary experiment 3---boundaries around letters): "It had been suggested that presenting letters in uniform rectangular areas defined by boundary lines might help to indicate the position of the letter in badly degraded copy. Therefore, two experiments were done comparing bounded and unbounded letters. In the boundary arrangement used, the cells were spaced by uniform white background, noise appearing within the cells only." (p. 8)

Result (preliminary experiment 3): "Legibility was found to be no better for the bounded than the unbounded arrangement and was found to be worse if the boundary lines coincided with the outer limits of the letters at top and bottom, leaving no noisy margin on those edges. In a second experiment, similar results were obtained employing black borders instead of white." (p. 8)

Procedure (preliminary experiment 4---columnar arrangement of letters): "The effect of presenting the letters in uniform columns was tested by comparing this arrangement with one in which the letters were not aligned in columns." (p. 8)

Result (preliminary experiment 4): "No difference was found." (p. 8)

Procedure (preliminary experiment 5---letter spacing): "It had been assumed that . . . all letters would be assigned the same amount of space in the line, as in typing, rather than variable spaces as in printing. . . With this arrangement, the closest spacing possible between letters for a given type face is that in which the uniform letter areas are the width of the widest letter. In the . . . test, letter areas of this size were compared with somewhat wider letter areas (i.e. with copy so printed that the average space between letters was somewhat greater)." (p. 8-9)

Result (preliminary experiment 5): "The wider spacing was found to be of no advantage for legibility." (p. 9)

Procedure (preliminary experiment 6---letter spacing): "A second spacing experiment included a narrower spacing arrangement in which the basic letter area was reduced by redesigning the widest letters (W, M and A)." (p. 9)

Result (preliminary experiment 6): "The data was inconclusive, but there was some indication that reducing the spacing below the narrowest spacing possible with the type face as originally designed impaired legibility." (p. 9)

Procedure (preliminary experiment 7---noise): "(D)ata were gathered on the relative legibility under noise of a number of equivalent type sizes at 14 inches, (4-, 8-, 10-, 12-, 14-, 24-, and 36-point sizes)." (p. 9)

Result (preliminary experiment 7): "The 8 to 12 point range of sizes appeared to be optimum. There appeared to be little or no difference in legibility within this range, while there was impairment of legibility for the larger and smaller equivalent type sizes." (p. 9)

Procedure (preliminary experiment 8---gray scale): "Optical density measurements of black and white noise-degraded copy were made over the available range of S/N (signal-to-noise) values." (p. 9)

Result (preliminary experiment 8): "Results indicated a discrepancy, probably of minor importance, from an optimum centering of the density range about a middle gray value." (p. 9)

Procedure (preliminary experiment 9---learning): "A further experiment (was) designed

to provide information on the amount of improvement produced by learning in the reading of noisy copy . . . ." (p. 9)

Result (preliminary experiment 9): This "indicated relatively small improvement. Data derived from later experiments showed that at the low error levels of practical interest virtually all improvements occur within eight experimental trials." (p. 9)

Procedure (preliminary experiment 10---experimental arrangements): Studied were "(a) the possible effect of mirrors used to increase the viewing distance, and (b) the effect of instructing the subject to work for speed." (p. 9)

Result (preliminary experiment 10): "Some indication was found that the mirrors might have a small effect on performance which could easily be allowed for. Instructing the subject to work for speed had the effect of reducing time scores, and for inexperienced subjects, it tended to increase error scores." (p. 9-10)

Procedure (preliminary experiment 11---experimenter error): "To validate (the) procedure the experimenter practiced recording responses . . . ." (p. 10)

Result (preliminary experiment 11): "Analysis of results indicated that . . . errors introduced by the experimenter . . . would be negligible." (p. 10)

Procedure (preliminary experiment 12---printing density): "Data were derived from several experiments testing the effect on legibility of differences in printing density observed between different rolls of recording paper and on the same rolls after varying lengths of time of exposure to the air." (p. 10)
Result (preliminary experiment 12): "These results showed no systematic differences between performance scores on stimulus materials differing in density, demonstrating that, within the range tested, printing density was not a substantial factor influencing legibility." (p. 10)

Procedure (preliminary experiment 13---visual noise variability): "(T)he effect of the visual noise pattern in degrading legibility varied considerably . . . A minor experiment was performed to get a rough measure of the variability in legibility between stimulus cards printed at the same S/N value." (p. 10)

Result (preliminary experiment 13): "Results showed a ratio of nearly six to one in estimated error level between the best and worst card. These results pointed out the necessity of employing a fairly large sample of printings in order to obtain precise and reliable estimates of the average legibility of noise-degraded copy." (p. 10)

Procedure (experiments on the noise variables): "Copy was prepared in the form of

scrambles of 26 (capital) letters; the letters being arranged in five lines of 5 letters each with a sixth line containing a single letter. The type face employed was (10-point) GOTHIC TEMPO in a heavy stroke width. In the test situation, stimulus cards were presented 8.5 inches behind an 11 inch square aperture in a vertical screen. Illumination at the reading surface was 72.9 foot candles. . . The subject was seated in a chair equipped with a headrest. In an experimental trial, the subject began reading aloud after a shutter dropped to reveal the stimulus card. Experimental instructions emphasized accuracy rather than speed. Both time and error scores were recorded. . . (p. 11) The twenty-four subjects, male students and laboratory personnel, were selected for 20/20 visual acuity on the Ortho-Rater at near and far distances. . . (p. 13) During the experimental periods, responses were recorded by individual letters so as to provide additional data on letter confusions to be used in later work on type design. . . (A)dditional controls employed in this experiment(al series) served to provide a definitive set of data on the effect of the 'noise' variables on legibility of unrelated letters." (p. 14)

Result (experiments on the noise variables): Curves derived from the data yielded the following conclusions:

1. "The legibility of noisy copy at a given definition decrease(d) at an accelerating rate with decreasing ratio of signal to noise.
2. "The legibility of noisy copy increase(d) systematically with increasing definition (printing elements per letter).
3. "At a given legibility level, the normalized energy per symbol ($E = N^2S/N$) varies only slightly over a wide range of definitions.
4. "The optimum definition, in terms of such small energy differences as occur(red), problems of equipment design, and various secondary considerations, appear(ed) to be in the neighborhood of 20 to 25 elements per letter height (400-625 elements per letter square)." (p. 42)

Procedure (experiments on typographical and related variables---capitals versus lower case for scrambled letters): "Experimental copy . . . was . . . printed in 30- and 36-point TWENTIETH CENTURY MONOTYPE. The capital letters . . . have definitions of 15 and 20 elements respectively in the vertical dimension. In lower case, because stems of some letters project above and some below the line, the overall vertical definitions . . . are 19.3 and 24.3 elements respectively. The lower case letters are, of course, narrower on the average. . . Overall printing area for capitals and lower case was identical, the smaller letter-width of lower case being compensated for by larger inter-letter spaces, and the greater vertical extension . . . by less space between the lines." (p. 16)

Result (capitals versus lower case for scrambled letters): "The test data were converted into normalized energy per symbol values for upper and lower case letters at a number of error levels. It was found that, for this particular printing arrangement, lower case require(d) more than twice as much energy per symbol as capitals under noise conditions producing 4 to 10 (percent) errors. These findings indicate that capitals are to be preferred for the immediate objective of the Infomax project." (p. 16-17)

Procedure (experiments on typographical and related variables---letter spacing): This experiment "tested the legibility of upper case, unrelated letters in two spacing arrangements. The . . . even spacing arrangement . . . was compared with proportional spacing, . . . in which the width of the letter cell varies with the width of the letter . . . giv(ing) a 27 (percent) saving in printing area. The test was made employing a single definition of 20 elements in the vertical dimension of the letter." (p. 17)

Result (letter spacing): "Although legibility was found to be poorer with proportional spacing, this was compensated for by the reduction of printing area. Consequently, proportional spacing turns out to be slightly more efficient in terms of energy per symbol requirements at two error levels. It can be inferred from these results that the optimal spacing for this type face would be found with proportional spacing, the average space between letters lying somewhere between the standard and proportional values tested . . . ." (p. 17)

Procedure (experiments on typographical and related variables---capitals versus lower case for meaningful material): "Ninety five-letter words were chosen from among the 500 most frequently used words in the language. . . printed five to a card, capitals and lower case on separate cards, in proportional spacing. Thirty-six point type was used. The vertical definition of words printed in capitals was 20 elements, that for lower case, 24.3 elements, but the mean letter cell for lower case was narrower. The definitions expressed in mean number of elements per cell were 355 for capitals and 367 for lower case. Total printing space requirements were therefore almost identical for the two cases." (p. 17) In the experiment, "(a) word was scored as either correct or incorrect . . . ." (p. 17)

Result (capitals versus lower case for meaningful material): "(A)t two relatively high error levels, capitals (were) more efficient than lower case . . ., the energy cost for lower case being about 50 (percent) greater than for capitals. This difference (was) not as great at that found between upper and lower case unrelated letters." (p. 18)

Procedure (experiments on typographical and related variables---unrelated letters and words): A comparison was made "between energy estimates for unrelated letters and for words, using data from .". . (p. 18) the previous two experiments. "It should be noted that, in computation of error percentages, the word (was) the unit of scoring in the word copy and the letter in the letter copy. The estimate of relative energy per symbol might (have been) somewhat different if the word copy had been scored by individual letters." (p. 18)

Result (unrelated letters and words): "(W)hen printed in capitals with all typographical variables equated, five-letter words are considerably more economical than sets of five unrelated letters, the energy cost for unrelated letters being about 50 (percent) greater than for words." (p. 18)

Procedure (experiments on typographical and related variables---letter size): "Six sizes were selected in the 5 to 24 point range. Capital letter scrambles printed at three definitions (15, 20, and 32 elements) were employed . . . at each of the type-size values. Each definition was printed at two S/N values. . . Twelve subjects were employed." (p. 19)

Result (letter size): "The results in general agreed with those of the exploratory experiments. An optimum was found in the neighborhood of the 10 point size. At the level of two errors in 26 tries the effect of type size was quite small with very little difference between 8 and 12 point. At the level of five to seven errors in 26 tries the loss of legibility with increasing size was more marked, the optimum region being 8 to 10 point." (p. 19)

Procedure (experiments on typographical and related variables---letter design): "Legibility test data generally show confusions among letters to be unevenly distributed over the alphabet, and the confusions can to some extent be related to obvious characteristics of the letter designs. . . There are a number of problems involved in . . . new designs . . . . A change of one letter sets up new relations within the set . . . and introduces the possibility of new confusions. . . Information theory suggests that the more two letters have in common, in terms of . . . their strokes, the greater the probability of their being confused. This suggests . . . a physical measure of overlapping stroke areas . . . substituted for confusion scores . . . This was done . . . . The correlation . . . of 0.75 (was) not high enough . . . (p. 20) (and t)he idea . . . was therefore dropped. . . A method was . . . devised for producing simulated noisy copy by superimposing over the letters (1) one or more layers of a Zip-a-tone screen bearing an irregular white dot pattern and (2) a photographic film positive of noise as produced in the facsimile printer. . . (T)he noise pattern can be changed quickly by slight shifts of the superimposed screens . . . The process of developing new designs involved . . . (f)irst, . . . division of the alphabet into the following four (confusion) groups:

1. "O, Q, D, G, C, U
2. "E, F, B, P, R, S
3. "Y, I, V, T, J, L, Z
4. "N, H, K, X, M, W, A

"Though there were some marginal cases, confusions within the groups were considerably more frequent than between groups. This grouping suggests that similarity in such characteristics of design as roundness, overall width, width greater at the top than at the bottom, etc. contributes to confusion. It can be further observed that there is considerable bias in the distribution of elements among the letters; (p. 21) for example, more letters have a vertical stroke on the left than on the right, more letters are relatively wide at the top than at the bottom. The detailed examination disclosed a tendency for a letter to be mistaken for one with a simpler outline more often than the reverse, and for a letter to be mistaken for one which occurs more frequently in the language more often than the reverse. . . As a second step, a large number of new designs was worked out, not with reference to particular letters which they might replace, but with a view to getting some idea of the

variety and type of patterns that might survive noise degradation. These designs were presented under simulated noise and rated for recognizability by a sampling of subjects. Results . . . justif(ied) discarding some items and retaining others. . . The next (third) step was to modify letters . . ., concentrating on the letters most often confused, and making as much use as seemed advisable of the designs which had survived the preliminary test. . . The revised alphabet . . . included about 15 characters modified in some degree . . . . The original and revised alphabets were then compared . . ., using simulated noise." (p. 22)

Result (letter design): "It was found that 50 . . . to 70 (percent) fewer errors were made on the revised . . . letters . . . . Learning on the new designs by the subjects was not a major problem. . . (p. 22) Results up to this time do not justify recommending a particular set of new designs. Such a recommendation should be based on more extensive testing with regular facsimile copy." (p. 23)

* * *

3322 Dixon-1948

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EFFECT OF EXPOSURE-TIME ON PERCEPTION OF GROUPED DIGITS

American Journal of Psychology, 61:3 (July 1948) 396-399, 4 refs.

Problem: Determine "the effect of variation in exposure time and fixation-point on immediate recall of digits grouped in 2s and 3s, as measured by immediate reproduction from tachistoscopic exposure." (p. 396)

Procedure: "The (subjects) were 108 college students (most of them Naval cadets), 18 for each exposure-time used. In Experiment 1 (no fixation-point designated) exposure-times of 100, 300, 450, and 700 (milliseconds) were used. In Experiment 2 (central fixation-point designated) exposure-time was at 100 and 450 (milliseconds). . . (p. 397) The Dodge tachistoscope was used with a 100-(watt) lamp at pre-stimulus and stimulus windows to insure good photopic vision. Exposure-time was measured and controlled . . . and light intensity was varied with exposure-time . . . to keep brightness photometrically constant . . . (p. 396) White stimulus-card was 5 X 9 (centimeters) on which were mounted six black digits, each 13 (millimeters) high, 8 to 9 (millimeters) wide, with stroke-width between 1-2 (millimeters). Each digit was alloted 1 (centimeter) space with 1 (centimeter) between each grouping. With identical allotment of space for digits and space between groups, the 000 000 grouping with 2-(centimeter) between the two groups was devised to be equivalent to the 00 00 00 grouping in total length. The digits were arranged in such an order as to give no advantage to position, serial location, etc. Eighteen series of six digits each were used, grouped in 7-(centimeter) 3s, 8-(centimeter) 3s, and 8-(centimeter) 2s, making a total of 54 cards. . . Written reproduction was required . . . . Correctness

of reproduction was measured by Weinland's weighted penalty method." (p. 397)

Result: In Experiment 1 (no fixation point), "the 7-(centimeter) 3s enjoyed a consistent advantage. The 8-(centimeter) 2s were equal . . . at the shorter exposure-times (100 and 300 milliseconds) . . .", (p. 397) and the 8-centimeter 3s were equal at the longer exposure-times (450 and 700 milliseconds). Thus, "(a)t the longer exposure-times the grouping in 2s was definitely less well apprehended than the grouping in 3s." (p. 398) In Experiment 2 (central fixation-point), "the grouping in 2s is unquestionably superior at short exposure-time (100 milliseconds), with the 3s improving somewhat (particularly for the 8-centimeter) at 450 (milliseconds)." (p. 398) Thus, "it was found that, at exposure-times precluding effective eye-movements, apprehension of grouped digits varied with number of digits encompassed within a more effective visual area. Where eye-movements were effective, digits grouped in 3s were apprehended better than digits grouped in 2s. Effective visual area and number of fixations required, as controlled by exposure-time, fixation-point and grouping-artifact, are offered as an economical, but not exclusive or complete, explanation." (p. 399) However, "the question as to whether digits are apprehended better when grouped in 2s or 3s has no absolute answer." (p. 398)

* * *

2196 Dodge-1907
Dodge, Raymond
Wesleyan U., Middletown, Conn.
AN EXPERIMENTAL STUDY OF VISUAL FIXATION
The Psychological Review Monograph Supplements, 8:4
(November 1907) 95 p., whole no. 35

Problem: Review the problems concerned with the previous work reporting on, and some experimental studies concerned with visual fixation.

Procedure and Result: The following outline of contents and interspersed summary statements show the scope of this rather extensive monograph:

I. The fixation field.

A. Visual fixation and its anomalies, as shown by recent photographic registration of the eye movements.

B. The physical origin of fixation movements; pulse, respiration, and the general oscillations in muscular tension.

C. Visual motives for fixation movements; retinal fatigue, and binocular coordination.

D. The inhibition of fixation movements.

E. The reaction time of the eye; apparatus and results.

F. The fixation object; normal variations in the point of regard and the importance of extra-foveal vision.

II. Adequate fixation.

A. The clearing-up process; its differentiation from after-image, and its demonstration.

B. Minimum duration of the clearing-up process; inadequacy of familiar tests. "(T)he tachistoscope offers the best conditions for the solution of our problem, provided we realize its limitations." (p. 32)

C. Tachistoscopic exposure; motives for minimal exposures, their fallacies and practical consequences. "(T)he only exposure, whose results will apply directly to normal processes, is that which, under the given experimental conditions of illumination, will permit a full and uniformly cleared-up visual impression." (p. 37)

D. Influence of the pre- and post-exposure fields; six experiments giving the minimal clearing-up time under variarion of the pre- and post-exposure fields. Experiment 1---given the following conditions:

| pre-exposure | exposure | post-exposure |
| --- | --- | --- |
| white/black | white | white/black |

"a maximum clearing up is only accomplished by an exposure of from (.5) to several seconds, according to the duration of the pre-exposure fixation." (p. 37) Experiment 2---given the following conditions:

| pre-exposure | exposure | post-exposure |
| --- | --- | --- |
| black | gray | white |

"an exposure of 50 σ (milliseconds) may utterly fail to reveal any trace of the gray." (p. 38) Above 20 σ, words printed in the style of type used in the Psychological Bulletin "became legible if they were increased in size, though . . . differential emphasis on . . . larger letters . . . remained. Words of the same sized letters were legible if the exposure was increased to 30 σ; or again, without changing the exposure time, if the relative illumination of the exposure field was slightly increased." (p. 40) Experiment 3---given the following conditions:

| pre-exposure | exposure | post-exposure |
| --- | --- | --- |
| white/black | gray | white/black |

"at 20 σ only that part of the phrase that fell on the black pre-exposure field was sufficiently cleared to be legible. . . Not until the exposure time reached 120 σ was it possible to speak of a full clearing up of the word on the white field. . . (D)ifferences (in contrast amount) persisted to 500 σ, beyond which the experiment was not carried." (p. 40-41) Experiment 4---given the following conditions (top = every other exposure, bottom = in between):

| pre-exposure | exposure | post-exposure |
| --- | --- | --- |
| black | word | white |
| white | word | black |

"(e)ach swing of the pendulum in the direction black, ex., white gave a legible exposure. Each swing in the opposite direction . . . gave an illegible exposure. This was directly contrary to expectation . . . ." (p. 42) In general, "(e)xperiment discloses an irregular variation of the clearing-up process consequent to a regular increase in the complication of the pre- and post-exposure fields." (p. 43) Experiment 5---given the following conditions:

| | pre-exposure | exposure | post-exposure |
|---|---|---|---|
| 1. | horizontal line where word will be | word | horizontal line where word was |
| 2. | several horizontal lines covering area | word | several horizontal lines covering area |
| 3. | five horizontal lines covering word area | word | five horizontal lines covering word area |
| 4. | vertical lines at letter spacing | word | vertical lines at letter spacing |

condition (1) rendered "uncertain and indistinct the otherwise adequate exposure of 30 σ." (p. 43) Condition (2) "failed to increase the disturbance." (p. 43) Condition (3) "appeared not only plainer than with [condition (1)], but . . . was clearer than without any complication at all." (p. 43) Condition (4) "almost completely obliterated the word. . . The most pronounced interference with the clearing-up process . . ., without decreasing the illumination . . ., was by a . . . complication of exactly the same general character as the exposure, i.e., by a word." (p. 44) Experiment 6---given the following conditions:

| pre-exposure | exposure | post-exposure |
|---|---|---|
| mirror image of word | word | mirror image of word |

"(a)s the time was reduced below 70 σ the inadequacy of the exposure became more and more obvious. But even 70 σ was obviously too short for an adequate clearing up." (p. 45) 125 σ seemed about right, while 170 σ seemed "unnecessarily long . . . With the same complication that made a 12(-point) word illegible when T = 70 σ, a 24(-point) word was entirely legible and fairly cleared up, and even a 16(-point) word was legible." (p. 45)

E. Normal interference of successive fixations; apparatus for approximating normal exposure, and the consequent variation from simple tachistoscopic, uncleared fixation pauses, and the approximate duration of adequate fixation. "Both experimentally and practically the operation of the visual clearing-up process precludes a succession of adequate visual fixations under .1 (seconds) each." (p. 50)

III. The complication of the visual process during fixation.

A. Eccentric vision in reading; the relative position of direct fixation in the complex reading process, and an experimental determination of the value of peripheral vision in shortening the period of direct fixation.

B. Successive elements of the process of perception; the perceptual unit in reading, the perceptual process subserved by peripheral vision, and the temporal differentiation of general and specific stimulation.

C. The determination of a new point of regard; the irrelevance of the precise fixation point, and its testimony concerning the object of regard.

IV. The organization of retinal elements.

A. The function of extra-foveal vision in space perception. "(T)he question forces itself . . . whether the more general traditional view of the spatial organization of the retina does not need thoroughgoing revision." (p. 65)

B. Retinal local signs; the functions of a local sign, motor local signs of the retina, experimental evidence for and against their existence.

C. A genetic organization of the retinal elements; differential integration of the retinal elements consequent to normal stimulation, the standardizing effect of eye movement, the development of foveal prerogatives, and a connecting bond between visual and tactual organization.

Appendix. The technique of recording the eye movements.

A. Introduction. Reviews the apparati and techniques of Delabarre, Huey, Cline, Judd, and the author.

B. The theory of the movements of the corneal reflection; limitations and precautions of registration by the corneal reflection.

C. The reliability of the corneal reflection records; difficulties of an experimental test, after-image control, artificial object, differential illumination, comparison of the movements of the corneal reflection and a fixed point of the eye. "(E)ven under the most accurate control it is doubtful if we can expect to eliminate errors under 10 (minutes of arc)." (p. 91)

D. The technique of the Wesleyan apparatus. "(T)he probability of error will be below the error of measurement. In a succession of fixations the error ought not to be more than 1 (degree). In general the maximum errors will be in the form of the slow drifts, which we observed in considering the relation of the head and eye movements. The smaller errors may be sharp and rapid corresponding to the pulse and respiration curves. Undoubtedly subjects vary in their control of the head movements and the variation in any given case should be tested out with the aid of the normal head lines." (p. 95)

* * *

English-1944

2657

English, E.

Iowa State U., Iowa City

A STUDY OF THE READABILITY OF FOUR NEWSPAPER HEADLINE TYPES

Journalism Quarterly, 21:3 (September 1944) 217-229

Problem: "(D)etermine if printing types commonly used in setting newspaper headlines differ in the ease with which they are read." (p. 217)

Procedure: The following prefacatory remarks are pertinent to the background of this experiment:

1. "Frederick W. Goudy, the greatest of American type designers, recently wrote (in a letter to English): 'I feel that too few (designers) realize that a type amply legible for one purpose may not prove so for another---there is no universal type---there is no universal quality of legibility for types for all purposes.'" (p. 217)
2. "(V)isibility (is) a term referring to the intensity of the psychophysical stimulus which evokes perception and discrimination. . . For the measurement of the visual threshold, . . . Luckiesh and Moss have developed a visibility meter. . . (which) reduc(es) or increas(es) the factor of brightness contrast." (p. 218) (see Luckiesh-1942, elsewhere in this volume)
3. "Sanford measured the 'legibility' of letters by noting the distance from the observer that individual letters could be read (distance threshold)." (p. 218) (see E. C. Sanford, The relative legibility of small letters, American Journal of Psychology, v. 1 (1888) 402-435)
4. "Burtt and Basch measured the degree that out-of-focus letters could be identified when projected on a screen." (p. 218) (see H. E. Burtt and C. Basch, The legibility of BODONI, BASKERVILLE ROMAN, and CHELTENHAM type faces, Journal of Applied Psychology, v. 7 (1923) 237-245)
5. "Criteria of reading fatigue include metabolism and pulse rate, variations in visual near point, eye movements, speed of accommodation, and rate of blinking. . . The blink rate method has not been found . . . acceptable by (some) experimenters . . . . McNally . . . concluded that 'there is need for further evaluation of the validity and reliability of eye-blink frequency as a criterion of readability.'" (p. 219) (see H. J. McNally, The readability of certain type sizes and forms in sight saving classes, Teachers College Contributions to Education, No. 883, New York: Columbia University, 1943)
6. "(R)eadability (including all the factors that affect ease of reading, i.e., visibility, visual effort, fatigue, etc.) . . . has been investigated by measuring work output, or speed of reading, of a group of readers. . . Tinker and Paterson. . . (use a) total time of 1-3/4 minutes . . . as a criterion of readability. . . (see Paterson-1940a, elsewhere in this volume) Luckiesh and Moss . . . employ speed of reading

as a criterion, however, . . . their subjects are instructed to read various typographical arrangements at their normal rates over rather long periods of time." (p. 219-220) (see Luckiesh-1942, elsewhere in this volume)

"(A)lmost all of the methods . . . mentioned have been concerned with body types. When display types have been measured, they have employed, with few exceptions, the criterion of visibility or visual fatigue as measured by the blink test. While high visibility is undoubtedly a basic factor in achieving high readability, it does not follow that this consideration alone should guide selection of headline types. . . Thus it was decided to construct a special headline reading test to measure the number of words read during uniformly brief exposure intervals." (p. 220) The parameters of the experiments were as follows:

Subjects . . . . Inter-family test: 45 university undergraduates in journalism and psychology, having 20/20 vision (Snellen chart) and a reading rate (Chapman-Cook Speed of Reading Test, Form A) for 1-3/4 minutes of 20.35 paragraphs (with a standard deviation of 4.51).

Subjective evaluation: 50 students other than the above.

Intra-family test: unspecified.

Typography . . Inter-family:

| face | leading solid | 1-pt. | 2-pt. | 4-pt. |
|---|---|---|---|---|
| BODONI BOLD (Roman group) | - - - | 14-point | 24-point | 30-point |
| KARNAK BOLD (square serif group) | 14-point | - - - | 24- & 30-point | - - - |
| TEMPO MEDIUM (Gothic sans-serif group) | 14-point | - - - | 24- & 30-point | - - - |

Subjective: same as inter-family.

Intra-family: CHELTENHAM BOLD in (1) REGULAR, (2) CONDENSED, and (3) all-capitals REGULAR; each in 14-, 24-, and 30-point.

Layout . . . . Inter-family: ". . . 45 3-line headlines (set flush to the left;) . . . 15 letter units (per) line (with 4-em space between words;). . . (a)rticles, prepositions, and conjunctions . . . not capitalized, unless they begin a line(;). . . (n)umerals in figure form and abbreviations requiring use of capital letters are included (and counted as, e.g., 1934 = 2 words, 6c = 2 words, WAC = 3 words, and A.W.O.L. = 4 words;). . . viewing of the words in the first two lines generally does not permit successful guessing of successive words in the last line(;). . . (f)or words that a reader would apparently expect to find in the last line, a substitution has been made of words of similar external outline but of different internal structure(;). . . distribution approximates the normal curve . . . as to degree of difficulty(;). . . number of words in each headline is well within the number of meaningful words that may be immediately recalled after one presentation." (p. 220)

Subjective: same as inter-family.

Intra-family: "experimental design . . . identical with the treatment employed in the earlier (inter-family) study." (p. 227)

Presentation . . Inter-family: random (Graeco-Latin square for each group of three readers) in a modified Seashore spark gap chronoscope with a three-inch-square opening---450 millisecond exposure with field of stimulus 14 inches from subject's eyes.

Subjective: "method of paired comparisons . . ." (p. 226)

Intra-family: same as inter-family.

Environment . . Inter-family: paper = newsprint, illumination = 50 foot-candles constant, area around stimulus opening in newspaper pages.

Subjective: unspecified.

Intra-family: same as inter-family.

Task . . . . . . Inter-family: recognition.

Subjective: appreciation.

Intra-family: recognition.

Response . . . Inter-family: written.

Subjective: judgment.

Intra-family: written.

Test . . . . . . Inter-family: accuracy (with analysis of variance).

Subjective: preference.

Intra-family: same as inter-family.

Result: The following conclusions were drawn as a result of the experiments:

1. "Printing types under consideration in this study have been shown experimentally to differ in readability as herein defined." (p. 229) This is somewhat contrary to the following statement by Tinker and Paterson: "'In spite of the opinion of publishers and printers as well as of readers to the effect that marked differences in legibility will characterize different type faces, our tests show that type faces in common use are equally legible.' Only AMERICAN TYPEWRITER and CLOISTER BLACK ('OLD ENGLISH') compared unfavorably with several commonly used OLD-STYLE and MODERN faces, their tests revealed." (p. 222)
2. "The CHELTENHAM BOLD, BODONI BOLD, and TEMPO BOLD families were found superior to KARNAK MEDIUM in the qualities measured in this test (sic).
3. "CHELTENHAM BOLD all-capitals retard the speed with which headlines are read approximately 18 per cent as compared with the lower case of this design.
4. "There is no reason to believe that the readability of headlines is fairly constant in the size range between 14 point and 30 point, inclusive.
5. "Reader judgment was found to be an unreliable index of the readability of type in headline form as measured by objective methods.
6. "To increase the assurance that news presentation to readers occurs under optimum reading conditions further investigations of other headline type families seem justified." (p. 229)

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3457 Erdmann-1898

Erdmann, Benno and Dodge, Raymond

PSYCHOLOGISCHE UNTERSUCHUNGEN UBER DAS LESEN AUF EXPERIMENTELLER GRUNDLAGE (EXPERIMENTAL PSYCHOLOGICAL RESEARCH ON READING)

Niemeyer, 1898, 360 p.

Note: As is indicated above, this work is one of the earliest authoritative studies in the field of readability of text. However, it is not only an historical document, but includes also rather complete descriptions of Raymond Dodge's early tachistoscopic and chronographic apparati. In this light, its contents would be of interest to those experimenters interested in aspects of the legibility problem other than the readability of text exclusively. The difficulty encountered in using this document is not only that it is in German, but also that its German is of an idiom now almost 70 years old. As being indicative of its contents, the following paragraph is extracted from the Foreword: "Die nachstehende Untersuchung ist aus psychologischen Übungen über das Lesen hervorgegangen, die im Wintersemester 1894/95 an der Universität Halle von dem Unterzeichneten geleitet wurden. Ich hatte in diesen Übungen die Anforderungen an einen Expositions-Apparat darzulegen, der binokulare Beobachtungen, sichere Akkommodation der Augen sowie simultanes Auftauchen der Schriftzeichen, und zwar auch von Wortreihen in Zeilenform gestattete. Auf diese Anregungen hin entwarf einer der Teilnehmer an jenen Übungen, Herr Raymond Dodge, selbständig die Skizze eines solchen Apparats, sowie überdies den Plan zu einem neuen, ebenso einfachen wie sicher funktionirenden Chronographen. . . Prof. Dr. Benno Erdmann." (p. iii-iv)

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3345 Flores-1960
Flores, Ivan
Dunlap and Associates, Inc., Stamford, Conn.
METHODS FOR COMPARING THE LEGIBILITY OF PRINTED NUMERALS
Journal of Psychology, 50:1 (July 1960) 3-14, 6 refs.

Problem: Compare the legibility of five, stylized, prospectively machine-readable, numeric type fonts.

Procedure: In the first experiment, twenty-seven literate subjects tachistoscopically viewed random, individual digits in each of five type fonts identified as GOTHIC, AIR FORCE, STANFORD RESEARCH, EXPERIMENTAL (examples not provided), and PARK AVENUE. Each digit was illuminated for approximately ten milliseconds, viewed through a light-tight port in the tachistoscope at approximately normal reading distance, and verbally identified to the experimenter in the interval between presentations. Errors were recorded. In a second experiment, the same subjects read a several-digit number to the experimenter from five (one for each font) series of check-simulating documents. Time and uncorrected errors were recorded.

Result: For the first experiment, the results of an "F" test were highly significant. A "t" test showed a statistically significant difference between all but the STANFORD RESEARCH and EXPERIMENTAL fonts. The author indicates a superiority for the AIR FORCE font. For the second experiment, an "F" test showed that differences among times were highly significant. A "t" test showed a significant difference between the AIR FORCE and the other four fonts. This experiment indicated that the identification may have depended upon a similarity in the type to that normally encountered.

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2659 Foley-1956
Foley, P. J.
Defence Research Medical Labs. (Canada)
EVALUATION OF ANGULAR DIGITS AND COMPARISONS WITH A CONVENTIONAL SET
Journal of Applied Psychology, 40:3
(June 1956) 178-180, 7 refs.

Problem: "This is a report upon four experiments carried out with the revised set (of LANSDELL digits) to answer the following questions:

1. "What are the confusion errors?
2. "Is the legibility of these digits independent of whether they are presented as black . . . on . . . white . . . , (or vice versa?)
3. "Is the set more legible than a typical conventional set under varied conditions of exposure and illumination?
4. "Is this set more legible than a typical conventional set when the digits are viewed obliquely?" (p. 178)

Procedure (general): "The conventional set chosen for comparison was that of MACKWORTH. . . because it shows consistently high performance in comparisons made by other investigators. . . (In) all experiments . . . (t)he digits were presented singly to the (subjects, who ranged in age from 18 to 37, and all of whom had 20/20 or better binocular acuity, ) who viewed them (on a 3- by 3-inch white Bristol board screen, from) a distance of 20 feet. . . The room . . . was dark. . . (E)xposure time, rate of presentation, and illumination level (on the screen) were controlled . . . (W)hen projected on the screen (all digits) were 3/8 (inch) high." (p. 178)

Foley-1956

Procedure (experiment 1): "Digits were exposed singly for .6 second . . . (at) one . . . every three seconds. . . (I)llumination . . . on the screen was ten foot-candles. There were 15 (naive subjects).". . (p. 179) who each viewed 30 presentations of every LANSDELL digit.

Result (experiment 1): "The specific confusions which contributed more than 5 per cent to the total error were the 3 with 5 (6.12%), the 3 with 7 (6.0%), the 5 with the 3 (6.6%), the 9 with the 5 (5.2%), and the 0 with the 8 (8.9%)." (p. 179)

Procedure (experiment 2): "Revised LANSDELL digits, black on white, were compared with . . . white on black, at . . . 10, 30, and 50 foot-candles. . . exposed singly for .5 second . . . every three seconds. . . There were 10 (subjects) drawn from the 15 used in Experiment 1." (p. 179)

Result (experiment 2): "(D)ifferences between (subjects were) significant . . . . None of the subject interactions (were) significant, however . . . . The interaction between digit type and illumination level (was) significant . . . (, i.e. when) the illumination level was of the order of 10 foot-candles, then white digits on a black ground (were) more legible; (while) . . . from 30 to 50 foot-candles, th(e) black . . . on . . . white . . . (were) more legible." (p. 179)

Procedure (experiment 3): "Revised LANSDELL . . . were compared with MACKWORTH digits, (all) black on white at . . . 10, 30, and 50 foot-candles, and . . . (0.3, 0.8, or) 1.3 seconds. . . every three seconds. . . Six (subjects) from Experiment 2 were used." (p. 179)

Result (experiment 3): "(T)he difference between the legibility of the revised LANSDELL . . . and the MACKWORTH digits (was) highly significant . . . (I)nteraction between exposure and digit type was not significant. There (was) a highly significant increase in percentage correct from (.3 to 1.3 seconds exposure time) . . . Similarly for illumination levels---as illumination increase(d) . . . ---there (was) a highly significant increase in percentage correct . . . ." (p. 179-180)

Procedure (experiment 4): "Revised LANSDELL . . . were compared with MACKWORTH digits, (all) black on white, at three angles of view, 45 (degrees) left, normal, and 45 (degrees) right. . . exposed singly for .8 second . . . every three seconds. The (screen) illumination . . . was 30 foot-candles. There were five (subjects).". . (p. 180) from Experiment 3.

Result (experiment 4): "The Revised LANSDELL . . . (were) significantly more legible than the MACKWORTH digits under these conditions . . . . There (was) no interaction between digit type and viewing angle. (For t)he degrees of freedom . . . the following comparisons (were) made: (a) 45 (degrees right) - 45 (degrees left); the difference (was) not significant . . . ; (b) 45 (degrees right) + 45 (degrees left) - 2 (normal); the difference (was) significant, and show(ed) a decrease in legibility between the normal and the oblique angle of view. None of the interactions approach(ed) significance." (p. 180)

Result (general): "The legibility of the new (LANSDELL) digits is not independent of . . . (contrast direction). At low illumination levels white on black is more legible, the reverse being true at high . . . levels. Comparisons with a conventional set, the MACKWORTH . . . , at different illumination levels, exposure times, and angles of view, show the new set to be significantly more legible under all of these conditions." (p. 180)

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2150 Foley-1957a

Foley, P. J. and Scott, D. M.

Defense Research Medical Labs. (Canada)

LEGIBILITY OF LEROY DIGITS AS A FUNCTION OF SIZE, DISTANCE, ANGLE OF VIEW, AND ILLUMINATION LEVEL

DRML rept. no. 76-3, Jun 57, 7p.

AD-141 760

Problem: "(U)sing the LEROY STANDARD GOTHIC Lettering Guides. . . (,) study . . . the legibility of twelve sizes of digits . . . as a function of size, distance, angle of view, and illumination level." (p. iii)

Procedure: "Digit sizes ranged from .06 . . . to .5 inches in height. Five viewing distances were . . . 2, 4, 8, 16, and 32 feet; three viewing angles at each distance (were) 45 (degrees right), normal, and 45 (degrees left); (and) three conditions of illumination (were) 1, 10, and 50 foot-candles." (p. iii) Digits were drawn in "5 rows of 10 (on 11- by 12-inch white Bristol boards), such that both the horizontal and vertical distance between consecutive digits, measured from the centres, was one inch. . . Thirty (Canadian Army personnel) subjects were used. . . All had 20/20 binocular visual acuity at near and far . . . Subjects read the digits aloud to the Experimenter . . . ." (p. 1-2) The following were the pens and templates used to obtain the stroke-widths shown:

| pen size | template no. | pen no. | stroke width (inches) |
|---|---|---|---|
| 1 | 60 | 00 | .010 |
| 2 | 80 | 00 | .010 |
| 3 | 100 | 00 | .010 |
| 4 | 120 | 0 | .015 |
| 5 | 140 | 1 | .020 |
| 6 | 175 | 2 | .025 |
| 7 | 200 | 3 | .030 |
| 8 | 240 | 3 | .030 |
| 9 | 290 | 4 | .040 |
| 10 | 350 | 4 | .040 |
| 11 | 425 | 5 | .055 |
| 12 | 500 | 6 | .070 |

(above from p. 2)

Result: "Results are presented showing per cent of the population reading each digit size with one hundred per cent accuracy, at each viewing distance, from each viewing angle, and under each illumination level. . . (p. iii) (W)ith the exception of the 2 (foot) viewing distance under 10 and 50 (foot) candles illumination, the digits . . . (were) always more legible when viewed from the left than from the right. . . The data show that the only digit which has a large increase in confusion errors when viewed from the right is the digit 9,

although the digit 6 has almost as large a decrease." (p. 3) The data are presented graphically.

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2151 Foley-1957b

Foley, P. J.

Defence Research Medical Labs. (Canada)

LEGIBILITY OF MOVING DIGITS AS A FUNCTION OF THEIR SEPARATION AND DIRECTION OF MOVEMENT

DRML rept. no. 76-4, Aug 57, 5p.

AD-145 725

Problem: Investigate "(t)he maximum speed of moving digits (on a screen) at which correct identification is possible . . . ." (p. iii) Use "the separation between digits . . . and the direction of movement.". . (p. iii) as variables.

Procedure: "Digits were inscribed, using UNO PEN Stencils, on transparent tapes. . . Three separation distances were used, .75 inch, 1.5 inches, and 2.0 inches, subtending visual angles (at 8.8 feet from the subject) of $6.4^{\circ}$, $12.8^{\circ}$, and $25.6^{\circ}$ respectively. . . A Keystone projector was modified so that tapes could be moved . . . in any direction (right-left, left-right, up-down, and down-up). . . (It) projected (the digits) onto a screen . . . (at) speed(s) . . . increased in discrete steps of $2^{\circ}$ per second, until the subject (of which there were five males who each had 20/20 vision or better) no longer gave 100 (percent) correct responses. . . The . . . actual legibility (visibility of the digits) was not a factor." (p. 1)

Result: The following table "shows the average maximum speed, in degrees per second, at which (the) subjects could correctly identify a series of 25 digits(:)

| | separation | | |
|---|---|---|---|
| direction | 6.4 | 12.8 | 25.6 |
| right-left | 31.6 | 49.4 | 63.6 |
| left-right | 30.4 | 46.8 | 59.6 |
| down-up | 28.2 | 37.4 | 54.4 |
| up-down | 25.6 | 32.6 | 49.8" |

(above from p. 2)

The results of an analysis of variance show "that all main effects are significant. There is, however, a significant interaction between the separation of digits and the direction of movement. . . The differences in the maximum speeds that can be tolerated for each direction appear to become accentuated as the separation increases. Further, increases in separation up to $12^{\circ}$ result in proportionately greater maximum speeds when the direction of movement is in the horizontal dimension. . . The superiority of movement from right to left . . . probably reflects the normal . . . reading habits . . . The superiority of movement upwards can be similarly explained." (p. 3) In conclusion, it is

seen that "more digits can be presented and correctly identified . . . , if the speed is slow and the separation small, than if the speed is fast and the separation large." (p. 3)

* * *

2578 Forbes-1951

Forbes, T. W., Moskowitz, Karl and Morgan, Glenn
Institute of Transportation and Traffic Engineering,
U. of Calif., Berkeley, and California Div. of Highways
A COMPARISON OF LOWER CASE AND CAPITAL LETTERS
FOR HIGHWAY SIGNS
In PROCEEDINGS OF THE THIRTIETH ANNUAL MEETING, 1951,
Roy W. Crum, Fred Burggraf, and W. N. Carey, Jr., Editors,
(Washington, D. C., Highway Research Board, National Research
Council, 1951), Vol. 30, p. 355-373

Problem: Compare the legibility (for scrambled letters) and recognition distances (for familiar names "with" and "without" previous knowledge by the subject as to the names to be presented) of lower case versus all capital letters (each in three different sizes) for highway signs under both daylight and night conditions. Ascertain whether the results compare favorably with the results of previous experimentation that "have shown that lower case printing gives more rapid reading than solid black printing with capital letters." (p. 356)

Procedure: All letters were semi-matte white on a black background. "The capital letters were rounded standard (U.S. Bureau of Public Roads)SERIES E (average letter width of (1) neat letters = 0.81, and (2) letter plus spacing = 1.13, both in inches per inch of letter height) but with a slightly widened stroke (0.20 inches per inch of letter height). The lower case alphabet was one based on practical trial and development (average letter width of (1) neat letters = 0.77, and (2) letter plus spacing = 1.15, both in inches per inch of 'loop' height---vertical strokes 0.22-0.25, horizontal strokes 0.20-0.22 inches per inch of 'loop' height, depending on letter---stem height of 'b', 'd', and 'k' = 1.415 inches per inch of 'loop' height). . . (p. 358 & 370) (L)ower case letters were chosen whose average width including spacing would be very close to that of the capital letters including spacing. . . (p. 361) (The) three types of test signs. . . were: (1) scrambled letters in a six letter combination (24 of the 26 possible letters were used) for determination of true legibility (involved letter discrimination); (2) familiar (geographic---local) names 'without knowledge' (by the subject) as to the names which would be used (involved letter discrimination and word pattern recognition); and (3) familiar names 'with knowledge' (involved word and over-all pattern recognition). Both lower case and capital letters were used in all three types of observations and in different sizes of letter (height = 6.0, 8.5, and 13.0 inches for capitals, and 'loop' height = 5.3, 8.0, and 12.0 inches for lower case). . . (T)he . . . determinations with the scrambled material were used as a base and the

observations of familiar signs were related to them." (p. 370) Observations were made by an average of 55 subjects (age 18-70 years) for each condition. Observations were made at night (12 to 18 foot lamberts . . . obtained from fluorescent tubes above and below the sign---30 to 40 foot lamberts gave blurring at longer distances) and during the daytime with the sun on the face of the signboard. The signboard carried six words (each 6-9 letters in length) at a time (the same word---of four for day and four for night---was used for each condition, case, and size). The signboard was 24 feet long by 6 feet high, with the bottom edge 17 feet above the ground. Thus, "measurements were carried out in full scale. . . against an outdoor background . . . 'Distance seen' was analyzed on the basis of known psychological factors into (1) recognition by overall word pattern and (2) actual discrimination of letters, as the two extremes. . . (p. 356) Where large numbers of porcelain enamel signs are involved, the amount of sign area required per letter is of importance in determining cost. An analysis was therefore desired of median 'distance seen' in (these) terms . . . In order to make such a determination, assumptions as to minimum vertical spacing between words and vertical spacing for margins were necessary. In the case of capital letters, . . . experience . . . indicate(d) that a border width equal to the letter height above and below each word is satisfactory to eliminate blur from the brightness of the sky or fusion between two words when arranged one above the other. For a two line sign, this gives a vertical spacing of 2.5 letter heights per line . . . For the lower case letters, however, the vertical spacing required to obtain an equivalent isolation of words was not clear. If the same factor were used on the basis of stem height . . ., it would result in a greater effective area of vertical spacing . . . (A)lternative assumptions were therefore made for exploratory purposes. The first . . . was . . . 2.5 'loop' heights . . . The second . . . was . . . 2.25 'stem' heights per line . . . ." (p. 366)

Result: Concerning the foregoing, "a considerable advantage resulted for the place names 'with knowledge' when (assumption one) was made. However, on this basis there was very little difference between lower case and capital letters for the scrambled letter legibility distances. On the other hand, (the second assumption) made the lower case and capital letters about equally effective in the case of the most familiar test material and showed the lower case at some disadvantage in the names 'without knowledge' and the scrambled letter determinations. The effects of the two assumptions were similar for day and night conditions except that differences obtained were smaller for the latter. . . (p. 366) (A) series of observations should be carried out to determine the minimum vertical spacing necessary for the two forms of letter." (p. 371) Returning to the primary variables (letter case, letter size, illumination level, and word composition), the following approximate 85 percentile (representing 20/20 vision) distance values (in feet) were derived from the observation data (equivalent letter and 'loop' heights interpolated from chart plot):

| | letter or 'loop' ht. | daylight capital letters | daylight lower-case | night capital letters | night lower-case |
|---|---|---|---|---|---|
| scrambled | 6 inches | 320 | 370 | 250 | 255 |
| letters | 8 inches | 450 | 500 | 350 | 355 |
| - - - - - | 12 inches | 700 | 755 | 530 | 545 |
| without | 6 inches | 445 | 480 | 310 | 420 |
| know- | 8 inches | 605 | 640 | 510 | 560 |
| ledge - - | 12 inches | 950 | 960 | 800 | 855 |
| with | 6 inches | 500 | 635 | 400 | 480 |
| know- | 8 inches | 720 | 850 | 560 | 640 |
| ledge - - | 12 inches | 1150 | 1255 | 900 | 960 |

(above from p. 364)

"For both lower case and capital letter signs, the median and 85 percentile distance increased as the degree of familiarity increased. The longest recognition distances however, were reduced more nearly to those of the second type under night conditions. . . The legibility distances from 'scrambled' letters were in line with (previous results) . . ., and decreased at night for the capital letters . . . Median legibility distances from the scrambled material proved to be roughly three-fourths as great as the recognition distances determined with familiar names . . . 'without knowledge' . . . . This relationship was also approximately the same for night observations. . . Letter height has been used rather generally as a basic index of capital letter size since it is constant for all letters . . . . For the lower case letters, however, . . . 'loop' height was the only constant dimension. When distance 'seen' was plotted against loop height, comparison of median distances showed an increasing advantage for lower case . . . over capital letters as familiarity of test signs increased. However, when stem height was used the advantage was reversed. . . Approximate eighty-five percentile distances for scrambled capitals and place names 'without knowledge' were 55 and 75 (feet) per inch of letter height. For lower case letters of equal 'loop' height, these distances were about 10 per cent greater. . . (p. 371) (P)revious studies . . . show(ed) that observations of legibility distances of highway signs resulted in a rather symmetrical frequency distribution of distance values, and here again similar distributions were obtained." (p. 361) In conclusion, "(o)n the basis of width, the lower case words could be seen farther than the capital words, presumably because they were higher. Thus where length of sign is the controlling factor, . . . these . . . would have the advantage. . . On the basis of sign area, the advantage . . . depends upon the vertical spacing or margins." (p. 355) Discussion following presentation of the paper brought out the following: (1) "the difference in distance seen . . . of only 10 percent does not seem significant enough to warrant immediate widespread use of the lower case letters", (p. 371-372) (2) "(d)irect comparison of capital letter height to the loop height of the lower case letters is not strictly correct", (p. 372) and (3) "(i)n usual use, the lower case letters for names involve a higher or capital initial letter, which requires more board space." (p. 372) In reply, the author states that "the question of how to compare the two forms of letter is much more complex than it may appear at first glance." (p. 372)

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2153 Gleason-1947

Gleason, J. G.

Purdue U., Lafayette, Ind.

THE DESIGN OF NUMERALS FOR USE IN COUNTER-TYPE INSTRUMENTS: A REVIEW OF THE LITERATURE

Rept. no. 166-I-39, 20 Dec 47, 24 p.

ATI-31 814

Extract: "The works reviewed (of which Berger-1944b and Luckiesh-1937a may be found elsewhere in this volume) appear to provide adequate information (except for styles and stroke-width) concerning the characteristics of the variables studied (size of the critical detail to be perceived, contrast between object and background, brightness level to which object is illuminated, time the image is allowed to rest on the retina, color of the image/ background, height of numeral, stroke-width of numeral, and interactions among these variables). . . These may be summarized as follows:

1. "The size of the critical detail in the numerals should be as large as is possible within the necessary practical limitations of overall size. Within these limitations, it may be said that the larger the numeral of any given type, the greater will be its visibility . . ., the more rapidly it can be identified, . . . the smaller the contrast ratio required . . ., the lower the brightness level required . . . .
2. "The contrast between the numeral and its immediate background should be as great as it is possible to provide. By increasing this contrast ratio for any given numeral type, equal visibility may be maintained when the size is reduced, or the brightness level is reduced, or the time for apprehension is reduced.
3. "The brightness contrast between the dial area and the surround should preferably yield a ratio of one. If this is not possible, a reduction of surround brightness below the level of the dial area reduces legibility only slightly. A situation which yields surround brightness greater than dial areas is to be strenuously avoided as this condition greatly reduces acuity.
4. "The brightness level of the numeral and its background should be as high as possible in the situation obtaining. Increasing the brightness level increases the speed and accuracy of apprehension and with the same type numeral a given visibility level may be maintained by increasing the brightness level while decreases in contrast . . . or . . . size are made, or while time for apprehension is decreased.
5. "For greatest visibility, other factors held equal, numerals should be either black or white on opposite background. In order of decreasing visibility, . . . inferior to black on white or (vice versa), are black on yellow, yellow-green, orange, green, red, blue-green, and blue. The question of the relative merits of black on white and (vice versa) has not been conclusively answered . . .

"(E)ach of the above factors should be applied to the greatest extent compatible with other requirements . . . (S)tyle of numeral and width of stroke used . . . have not been

adequately investigated. . . Therefore, . . . study of the design of numerals for use in counter-type instruments is conceived to be the study of these two factors while holding the (other) variables constant." (p. 18-19)

Note: Of the author's 67 references, which formed the basis for his literature review, the majority are concerned with such problems of perception as visual acuity, object-field contrast, size of critical detail, and the time an image is allowed to rest on the retina, and for these areas extensively covers material that is not included in this handbook.

* * *

3317 Green-1953

Green, B. F., McGill, W. J. and Jenkins, H. M.
Lincoln Lab., Mass. Inst. of Tech., Lexington
THE TIME REQUIRED TO SEARCH FOR NUMBERS ON
LARGE VISUAL DISPLAYS
Technical rept. no. 36, 18 Aug 53, 15p.
Contract AF 19(122)-458
AD-21 109

Problem: "(D)etermine the amount of time that is lost in searching for numbers on typical visual displays." (p. ii)

Procedure: Seven experiments were conducted "in order to determine . . . time . . . lost in searching . . . (and) some of the variables that influence search times. . . The displays used . . . were circular areas in which three-digit numbers were distributed at random. In some experiments, the displays were projected on a vertical beaded screen; in the others, numbered plastic tokens were arranged on a horizontal circular table top. In some cases, the background was uniform, or uncluttered; in other cases, a cluttered background was used. The properties of the numbers on the display were varied during the experiments, and the effects of these variations were noted in terms of their influence on search time." (p. 1) In Experiment 1 (numbers projected onto a 42-inch diameter screen 10 feet from each of 20 subjects), "the variables controlled were: (1) Number density: - . . . 25, 50, 75, or 100 three-digit numbers . . . . (2) Number size: - . . . 1/2 . . . or 3/4 inch high. . . (3) Number orientation: - . . . upright . . . (and) jumbled in eight different orientations 45 degrees apart." (p. 1) In Experiment 2, 17 new subjects read numbers under "nine experimental conditions: eight single orientations and one random orientation." (p. 6) Other conditions were fixed at 50, 3/4-inch numbers. "Experiment 3 was performed in order to determine whether . . . some numbers were easier to find than others. In (it), each of 12 subjects searched for the same 24 numbers. . . (in) the condition of 50 . . . 3/4-inch numbers upright on the screen." (p. 7) Order of presentation was also a variable. "In (Experiment 4) . . . , the projected displays included a polar

coordinate grid . . . , and each number on the display had a marker arrow near it. . . The numbers were 3/4 (inches) in height, and were all upright . . . . Five number densities were used: 20, 30, 40, 54, and 60 numbers, respectively. . . Each of 11 subjects was given four trials at each density. . . In Experiments 5 and 6, a horizontal (60-inch diameter) circular table top was used for the display. . . (which) was confined to an area 42 inches in diameter. The numbers were cut into small plastic tokens and the cuts were filled with fluorescent wax. . . On (a) small token the numbers were 1/8 inch high and were colored yellow. The larg(e) tokens had blue numbers 1/2 inch high. The background . . . was a polar coordinate grid . . . painted (green fluorescent) on vellum . . . The display was lighted with ultraviolet . . . in (a) . . . dark room. . . (T)okens (were placed) in a haphazard arrangement . . . (T)he experimenter announced the target number . . . . (Subject's) eyes were 3 to 4 feet from the display . . . (at an) angle of regard (of) about 45 degrees. In Experiment 5, (25, 50, 75, and 100) number densities were used with each token type separately . . . ." (p. 8-9) The eleven subjects used "had normal color vision. . . In Experiment 6, . . . 25 large blue . . . and 25 small yellow tokens (were placed) on the table and (the subject was) instructed to find a particular number of a specified color." (p. 10) The experiment was also conducted for 50 of each size token. Experiment 7 was an extension of Experiment 6. In it were added "some large yellow tokens of the same size and shape as the large blue (ones). For each token, separately, two density conditions were used: 25 . . . and 50 numbers. In addition, . . . 25 blue . . . (were combined) with 25 large yellow . . . and . . . with 25 small yellow tokens. . . For these . . . (there were) three conditions of search: search for a blue target number, search for a yellow target number, and search for a target number with color not specified." (p. 13) There were 12 subjects in this experiment.

Result: The following results and conclusions were drawn from the data:

1. "For legible numbers on a large visual display, the most important variable is the number of alternative numbers that must be scanned. For a moderate number of alternatives, the average search time in seconds is approximately one-fifth the number of alternatives.
2. "The search time is shorter for large numbers than for small numbers, unless there are so many numbers that the display becomes crowded. Smaller numbers are preferable on crowded displays.
3. "If the numbers on the display are all in an upright orientation, the search time is shorter than if the numbers are oriented at random . . . . However, if the numbers are all oriented in the same way and this orientation is not upright with respect to the observer, the search time depends on the . . . orientation. The average search time for all single orientations is equivalent to the search time for a display in which the various numbers are randomly oriented. Consequently, if operators must be located around a horizontal display where the numbers cannot be oriented properly for everyone, there is no advantage in arranging the numbers in a single orientation.

4. "Numbers at some positions in the patterns of numbers are harder to find than others, but the effect of location is very small.
5. "If the numbers are clearly legible, typical background clutter has no effect on search time.
6. "When the color of the number to be searched for is specified in advance, the presence of numbers of a clearly different color does effect the search time.
7. "Some individuals are faster searchers than others, but the differences are relatively small. . . (p. ii)

"In general, (the) data show that number-searching is a time-consuming process. It is not likely that search times can be reduced materially unless the number of alternatives to be scanned is reduced. When decisions must be made in a few minutes, delays up to an average of 30 seconds can be very costly. When speed is important, procedures involving number searches should be avoided." (p. 15)

* * *

3273 Gustafson-1960

Gustafson, Charles E.
Behavioral Sciences Lab., Aerospace Medical Div.,
Wright-Patterson Air Force Base, Ohio
A METHOD OF ESTIMATING SURFACE COLOR
DISCRIMINABILITY FOR CODING TRAINING EQUIPMENT
AND PREDICTING LABEL LEGIBILITY
WADD Technical Note 60-83, May 60, 8p., 4 refs.
Project 1710, Task 71607
AD-243 721

Problem: "(E)stimate the relative discriminability of colors solely on the basis of their relative brightness as obtained from spectrophotometric data or code approximations. . . Ignor(e) the effect of color contrast (contrast in hue) . . . ." (p. 7)

Procedure: "Using luminous reflectance values for Federal Standard colors, the classic formula for contrast is suggested as a convenient method of estimating surface color discriminability for purposes of coding training equipment and predicting the legibility of panel labels." (p. iii) A table is shown of "contrast and discrimination error percentages for selected Federal Standard color combinations. . . (p. 3) Specific applications of the method are discussed . . . ." (p. iii)

Result: "The following conclusions appear justified . . . .

1. "Brightness contrast between Federal Standard colors can be estimated by substituting available luminous apparent reflectance values (or code approximations) in the classic formula:

$$\text{contrast } (\%) = \frac{Y_1 - Y_2}{Y_1} \times 100$$

(in which Y = measured luminous apparent reflectance)

2. "As the brightness contrast between colors increases, the probability of committing errors in discrimination decreases and, conversely, as the contrast decreases, discrimination errors increase.
3. "In order to keep discrimination errors below 1 percent, contrast should be at least 75 percent or greater.
4. "As brightness contrast is reduced below 50 percent, the probability of committing errors in discrimination increases rapidly.
5. "Because brightness contrast is a prime factor in visual acuity, the legibility of printed labels involving combinations of Federal Standard colors (including achromatic) can be comparatively determined by means of the contrast formula . . . ." (p. 7)

* * *

3297 Halsey-1960a
Halsey, Rita M.
IBM Command Control Center, Federal Systems Div.,
Kingston, N. Y.
CHARACTER DESIGNS IN A 5x7 MATRIX OF SQUARES
Research rept. on ECPX-0027, Nov 60, 6p., 17 refs.
Contract AF30(635)-1404
AFCCDD-TN-61-3; AD-252 030

Problem: Determine the effect of brightness (of the characters) and size of individual elements (with center-to-center spacing held constant) on the legibility of numeric characters made up of a 5 X 7 MATRIX of squares. Also "generate a confusion matrix for the characters used, as an initial step toward designing a legible set of characters." (p. 133)

Procedure: The parameters expected to affect the legibility of alpha-numeric characters designed within a 5 X 7 MATRIX of squares are as follows:

1. "The form of the elements (circles, squares, blobs, etc.).
2. "The patterns, or designs, of the various characters.
3. "The size of the characters, relative to the viewing distance.
4. "The size of the elements, relative to the separation between the elements.
5. "The vocabulary to be used: whether alphabetic, numeric, or symbolically-coded characters will be included.
6. "The brightness of the on elements, and the brightness of the background (off-elements).
7. "Temporal factors.
8. "Interference among messages.
9. "Other factors specific to particular displays." (p. 133)

In the experiment, all factors but 4. and 6. were either arbitrarily fixed or held constant "at values expected by design engineers." (p. 133) Also, only 0.10-inch high (distance from center-to-center, top-to-bottom squares) numeric characters were used. Five styles (distinguished by the size of individual elements as defined below) were presented.

| measure | style of numerals | | | | |
|---|---|---|---|---|---|
| | A | B | C | D | E |
| ratio of side of element to distance between centers of elements | 0.1 | 0.3 | 0.5 | 0.7 | 1.0 |
| ratio of actual width to actual height of numeral | 0.67 | 0.68 | 0.69 | 0.70 | 0.71 |
| visual angle of one element at 36 inches viewing distance (in minutes (') and seconds ("') ) | 0'9.5" | (sic) 0'2.9" | 0'48" | 1'7" | 1'36" |

(above from p. 134)

Thus, five subjects tachistoscopically viewed (at 0.10-second flash duration) back-projected, luminous on opaque, 5 X 7 ELEMENT, randomly arranged, numeric characters at a distance of 36 inches, giving a visual angle of about "9.5 minutes" each. The illumination intensity of the character elements was varied (by means of neutral filters) between "a level yielding 100 percent correct identifications (and) a level yielding 0 percent correct identifications . . . (with) the intervening intensities in steps of 0.2 density." (p. 134) Room illumination provided a brightness on the background

panel of approximately 0.7 foot-lamberts. Accuracy was the test criterion.

Result: For the numeral sets used, the following results were obtained:

1. For a given style, accuracy increased as element illumination intensity increased.
2. To achieve equal performance, a higher intensity was required for style "A" than for "E" numerals.
3. Generally, the "results suggest that a simple relationship exists between element size and numeral intensity." (p. 135) Further, "it is reasonable to assume that as element size and/or brightness is further increased, legibility will reach a plateau and will finally decline as the character begins to resemble a blob." (p. 136)

Thus, "(i)t can be concluded that, for practical situations involving the ranges of sizes and intensities tested, area and intensity are roughly reciprocally related in determining legibility." (p. 135) Finally, the following conclusions were drawn from a confusion matrix generated by the results:

1. 7, 1, and 4 were correctly identified most frequently---5 and 8 least frequently. In general, accuracy decreased as the number of elements comprising the numeral increased. Also, the number of elements predicted inaccuracy better than it did accuracy.
2. "The numeral 1 was frequently reported as not being seen." (p. 137)
3. The numerals most frequently confused were as follows: 7 for 1; 4 for 2; 2, 4, and 7 for 3; 6 for 4; 3, 6, and 9 for 5; 4 for 6; 6, 9, and 0 for 8; and 6 and 8 for 0. However, a subjective numeral preference seemed to appear in that "more responses of 4 and 6 occurred than can be accounted for by confusion patterns." (p. 137)

There were no consistent differences between the confusion matrices for the different styles, although there was an indication that "larger or smaller elements seem to produce different sorts of confusions." (p. 137-138) A revised set of numeral designs (some old and some new) that should reduce some of the major confusions was shown. These designs have not been evaluated experimentally. When designs are limited to the 5 X 7 MATRIX shown, the above numerals "are appropriate only when no alphabetic material is used on the same display." (p. 138)

* * *

2662 Halsey-1960b

Halsey, Rita M.
IBM Command Control Center, Federal Systems Div., Kingston, N. Y.
FACTORS INFLUENCING THE LEGIBILITY OF SAGE DISPLAYS
Research rept. on ECPX-0027, Nov 60, 1v., 42 refs.
Contract AF 30(635)-1404
AFCCDD TN 61-7; AD-252 034L

Problem: Determine the effect of type, color, and amount of room illumination; tube brightness intensity; intensification time (a function of the time, in microseconds, alloted to the sweep in order to bring a symbol up to a viewable intensity of brightness); display rate; character size; and some interactions between these on the legibility of alpha-numeric characters and special symbols on a SAGE-type, shaped-beam, cathode-ray tube display. Present "infrequent repainting of information (every 2.5 seconds) requires that the system operate under a low level of blue light. The major complaints that have been made about the existing system were based on these conditions; namely, that there is too much flicker, too low an ambient light level, and too much information displayed on every console." (from the author's foreword) However, "(t)he primary requirement for alpha-numeric information on a SAGE display is legibility. This series of experiments uses a method which combines the tasks of detection and identification for information which does not move nor change with time." (p. 87)

Procedure: Fifteen experiments, designated (within the total experiment 4) A through O, involved a total of 46 subjects (IBM employees), ranging in age from 21 to 49, with a median age of 31. Most subjects had good vision. The following conditions were standard, and thereby fixed unless otherwise stated for a specific experiment:

1. Three SAGE consoles were set in a lusterless, neutral gray, painted room; with gray cloth screens as light baffles behind observers to eliminate ceiling reflections.
2. Tubes were 19-inch, shaped-beam, cathode-ray tubes, each using a P-14 phosphor, and having a 60 percent reflectance, a standard SAGE matrix painted in the center of the tube face, and a yellow implosion shield in place over the tube face.
3. Electrical conditions were those standard for XD-2 operation.
4. On the standard tubes used, the character height was 0.11 inches and the height to stroke-width ratio was 6 to 1. On the bright tubes, the following were seen: bright numbers 1 and 2 - height to stroke-width ratio of 5 to 1; bright number 3 - height to stroke-width ratio of 9 to 1; character heights on all bright tubes was 0.10 inches except when intentionally reduced to approximately 0.07 inches; bright number 3 also had SYMBOLS X, /, and \ without standard center dot X, /, and \.
5. Sixty-four alpha-numeric characters could be placed in the matrix, with P having a probability of 5/39 and all others a probability of 1/39. Ten numerics and 25 alphas were available.
6. All observations were foveal, with the observer's eyes 17 inches (and held by a brow-rest) from the center of the implosion shield. Dark adaptation was accounted for where necessary.
7. The observers' task was a recognition one (e.g. count the P's), with the response being by pushbutton, switches, or light gun.
8. Measurement criteria included reading time for static alpha-numeric characters, reading accuracy for changing SYMBOLS, and tracking performance.

The following variables were seen in the total experimentation:

1. Room illumination - type: normal ceiling, fixture, and bare ceiling.
2. Room illumination - color: SAGE blue, commercial blue, and white light.
3. Room illumination - amount: 0.004 to 1.0 foot-candles for SAGE blue, 0.6 to 15 foot-candles for commercial blue, and 0.017 to 13 foot-candles for white light, with 0.001 foot-candles (mostly white) in "lights off" condition. Amount of room illumination was varied by adjusting the input voltage between 0 and 120 volts, and in addition by the number of bulbs placed in the fixture mode.
4. Tube intensity: Brightness increased as the display rate increased. Two tube types, standard and bright, were used, with the bright having approximately 10 times the brightness of the standard. Relative brightness only was measured and varied between approximately 0.007 and 18.0. The following nomenclature was utilized to indicate the intensity of the two tube types: standard - minimum, low, medium-low, medium, high, and maximum; bright - minimum, low, medium, high, and maximum.
5. Intensification time was varied between 7 and 25 (standard) microseconds.
6. Character size was 0.10 (bright tubes) to 0.11 (standard tubes) inches height, except for two experiments in which it was (an average of) 0.07 inches.
7. Display rates (time between successive intensifications) were as follows: For alpha-numerics - 2.6 seconds (0.38 cycles per second), the SAGE standard; and 0.31 seconds (3.2 cps). For radar - 3.2 seconds (0.31 cps); and 2.3 seconds (0.43 cps).

For each of the individual fifteen experiments, the following title, purpose, conditions, and results, were seen (by experiment):

1. A - Effects of room illumination and tube intensity at the present SAGE display rate. Purpose: "(D)etermine the settings which would yield optimal performance on a legibility task." (p. 90) Conditions: Nine observers. Room illumination = 0.001, 0.004, 0.09, 0.26, and 1.0 foot-candles of SAGE blue light. Tube intensities = minimum, low, medium, and high on standard tubes. Display rate = 2.6 seconds. Seventeen of 20 possible interactions were tested. Results: "(T)ube

intensity is the most important determinant of legibility . . . ." (p. 91)

2. B - Effect of stray light. Purpose: Determine if "stray light from switches and pushbuttons interfered with visibility when the room lights were low." (p. 92) Conditions: Nine observers. "Selected conditions of Experiment A were run with and without the masking of stray light. The 'mask' condition was accomplished by draping opaque black cloth over all lighted units on the console and by taking extra precautions against stray light in the room. No other changes were made in programming, procedure, or conditions." (p. 93) Results: "The presence of stray light does not degrade performance . . . ." (p. 93)
3. C - Interaction between room illumination and display rate. Purpose: Determine whether a faster than standard display rate will permit higher and possibly white room illumination. Conditions: Six observers. Display rates = 2.6 and 0.31 seconds. Room illumination = 0.09 and 1.0 foot-candles of SAGE blue, and 0.017 and 1.0 foot-candles of white light. "At the fast rate, an illumination of 13 foot-candles of white light was also used. Standard tubes at <u>high</u> tube intensity were used." (p. 93) Nine interactions of these conditions were tested. Results: "At the standard . . . rate . . . , performance is much poorer under white light . . . , and . . . under higher levels of both kinds . . . . At the faster rate . . . , neither the color nor the amount of room illumination affects performance, except under 13 foot-candles of white light, where a decrement is noticed." (p. 94)
4. D - Interaction between tube intensity and room illumination at a fast display rate. Purpose: "(D)etermine if, for fast rates, lower tube intensities (than in C) also produced legible displays under high room illumination." (p. 94) Conditions: Six observers. Tube intensities = minimum and high on standard tubes. Room illumination = 0.09 and 1.0 foot-candles of SAGE blue; and 0.017, 1.0, and 13 foot-candles of white light. Display rate = 0.31 seconds. All conditions were tested. Results: "Under SAGE blue light, the two tube intensities produce equal legibility. Under white light, performance is poorer with the lower tube intensity. A high level (13 foot-candles) of white light produces a large decrement in performance." (p. 95)
5. E - Comparison of bright tube and standard tube. Purpose: Compare a bright with a standard tube "for legibility at both the center and the edge of the tube . . . ." (p. 96) Conditions: Six observers. Tubes = standard and bright number 1. Room illumination and display rate = 1 foot-candle each of SAGE blue and white light at 2.6 seconds, and 13 foot-candles of white light at 0.31 seconds. Matrix positions = center of tube and edge of tube. All combinations of variables were tested. Results: "(1) performance is better at the fast rate (even with high room illumination) than at the slow rate; (2) at the slow rate, legibility is better with SAGE blue room illumination than with white; (3) the matrix is easier to read at the center of the tube than at the edge; (4) the Bright tube is superior to the standard tube. . . Under the best observing conditions (0.31-second rate, center of tube), however, there is no difference . . . ." (p. 98)
6. F - Effect of intensification time at a fast display rate. Purpose: "(D)etermine the legibility of . . . information as a function of intensification time and room illumination." (p. 99) Conditions: Four observers. Tube intensity = maximum on standard and bright number 1. Intensification times = 7, 14, and 25 microseconds. Room illumination = 1, 6, and 13 foot-candles of white; and 1 foot-candle of SAGE blue light. Display rate = 0.31 seconds. All combinations of variables were tested. Results: "On the standard tube, legibility decreases as intensification time decreases and as room illumination increases. Excellent legibility was obtained with the Bright tube at all intensification times. The only objectionable decrement in performance was found when the 7-(microsecond) intensification time and 13 foot-candles of white room illumination occurred together." (p. 99)
7. G - Effect of character size. Purpose: "(D)etermine if 0.07-inch characters can be used under the proposed conditions (for SAGE-II) without degrading

legibility." (p. 101) Conditions: Eight observers. Display rate = 0.31 seconds. Intensification time = 14 microseconds. Room illumination = 1 foot-candle of SAGE blue, and 6 foot-candles of white light. Tube intensities = minimum, low, high, and maximum for the bright numbers 1, 2, and 3; and low, medium, high, and maximum for the standard tubes. Character heights = 0.10 (normal), and 0.065 to 0.075 (0.07 proposed) inches for the bright; and 0.11 inches for the standard tubes. Forty conditions were run in this two part (bright and standard tubes) experiment. Results: "0.07-inch characters are less legible . . . under conditions considered . . . . The decrement averages about 25 percent in scanning speed but varies with observing conditions. . . (A)ny decrease below maximum tube intensity will cause a further decrement in performance. Likewise, an increase in the amount of room illumination, or a substitution of whiter lights for the present SAGE blue, or an increase in the transmittance of the room illumination by the implosion shield, or a decrease in display rate, will probably degrade legibility to an unacceptable level." (p. 104)

8. H - Comparison of three sources for room illumination. Purpose: "(E)valuate the light source proposed by the MITRE Corporation for the SAGE-II Display System using Bright tubes." (p. 105) Conditions: Four observers. Room illumination = commercial blue fixtures at 0.6, 1.0, 3, 6, and 15 foot-candles of light. "SAGE blue, commercial blue, and white lamps were placed in the fixture to provide the . . . qualit(y) of illumination." (p. 105) Tube intensities = low and maximum for bright, and medium and high for standard tubes. Character sizes = 0.10 inches height on bright number 2, 0.065 inches height on bright number 3, and 0.11 inches height on standard tubes. Display rate = 0.31 seconds. Intensification time = 14 microseconds. Seven conditions of this experiment were tested. Results: "Illumination with SAGE blue results in better legibility than does illumination with commercial blue or white. The superiority of SAGE blue is more evident at higher illuminations. Commercial blue and white produce essentially equal legibility scores. Performance declines as illumination increases, but slowly at the lower levels. Decreasing tube intensity or decreasing character size also degrades legibility." (p. 106)
9. I - Legibility with changing symbology at a slow display rate. Purpose: "(D)etermine if conditions improving the legibility of static material improve or degrade the legibility of changing material." (p. 110) Conditions: Six observers. Display rate = 2.6 seconds. Tube intensities = minimum, medium-low, and high on standard tubes. Room illumination = 0.004, 0.09, and 1.0 foot-candles of SAGE blue; and 0.017 and 1.0 foot-candles of white light. All 15 conditions were tested. Results: "(A)t the standard SAGE rate, the conditions necessary for maximum legibility of static material also produce maximum legibility of changing material: high tube intensity, SAGE blue light, and low levels of ambient illumination." (p. 112)
10. J - Legibility with changing symbology at a fast display rate. Purpose: Determine "the legibility of overpainted material at a fast display rate." (p. 112) Conditions: Eight observers. Display rate = 0.31 seconds. Tube intensities = minimum, medium-low, and high on standard tubes. Room illumination = 0.017, 1.0, and 13 foot-candles of white. "The number of times the test numerals were painted was 1, 2, 3, or 4." (p. 112) All 36 conditions were tested. Results: "There is a complex interaction among the three principal variables: room illumination, tube intensity, and number of paints. . . (L)egibility increases as the number of paints . . . increases. . . (T)he higher the tube intensity the higher the percentage of correct identifications. The improvement is greatest for the highest room illumination . . . ." (p. 113) However, "(i)n general, performance deteriorates as room illumination is increased." (p. 114) Yet, "for N=1 and N=2, 13 foot-candles of room light actually produces better legibility scores than does one foot-candle, provided the tube intensity is high. . . (H)igh room illumination degrades the legibility of static material, but at the fast rate it may permit better legibility than

lower room illuminations under certain conditions. . . includ(ing) the requirement that the message be read on the first or second intensification . . . ." (p. 114)

11. K - Effect of room illumination on the discrimination of radar data symbols. Purpose: "(E)xperiment . . . with operator performance in handling Radar Data on Bright and standard tubes under various levels of SAGE blue and white room illumination." (p. 116) Conditions: Eight observers. Head rest removed. Display rate = 2.3 seconds. Tube intensity = maximum on two standard and one bright number 1 tube. Room illumination = 0.09 and 1.0 foot-candles of SAGE blue, and 0.017 and 1.0 foot-candles of white light. "(I)n the course of 16 runs, each (observer) was tested on each console under each room illumination." (p. 117) Results: "(O)perator performance is unaffected by the amount of SAGE blue room illumination; performance deteriorates as the amount of white room illumination increases; performance is better under SAGE blue light than under an equal amount of white light; performance is better with the Bright tube than with the standard tube." (p. 118)
12. L - Effect of increased SAGE blue room illumination on the discrimination of radar data symbols. Purpose: "(D)etermine if an even higher level of room illumination (than in the previous experiment) can be used." (p. 118) Conditions: Four observers. "Only two levels of SAGE blue room illumination were used: 1.0 foot-candle (normal ceiling) and 2.4 foot-candles (bare ceiling). All other conditions were as described for Experiment K." (p. 118) Results: There is "only a small decrease in performance (increase in time) as the amount of SAGE blue room illumination is increased from 0.09 to 2.4 foot-candles. Performance on the Bright tube is much better and less affected by room illumination than performance on standard tubes." (p. 118)
13. M - Effect of intensification time on the discrimination of radar data symbols. Purpose: "(D)etermine if intensifications shorter than the standard 25 (microseconds) degrade performance requiring the discrimination of radar SYMBOLS, which are repainted at relatively slow rates." (p. 119) Conditions: Four observers. Head rest removed. Tube intensity = maximum on one standard and two bright tubes. Intensification times = 7, 14, and 25 microseconds. Display rates = 2.3 and 3.2 seconds. Room illumination = 1 foot-candle each of SAGE blue and white light. Eleven of the twelve combinations of variables were tested. Results: "An intensification time of 14 (microseconds) is acceptable for (radar data) at both display rates . . . . Performance is about equal with 14 and 25 (microseconds) of intensification . . . . A 7-(microsecond) intensification brings about a decline in performance. . . The Bright tubes allow the operator to perform better than does the standard tube. In general, SAGE blue . . . permits better performance than does white room illumination . . . Comparison between the data for the two rates is not justified because of peculiarities of the program." (p. 120)
14. N - Comparison of three sources for room illumination, using normal consoles for the discrimination of radar data. Purpose: "(D)etermine whether commercial blue room illumination, as proposed by the MITRE Corporation, permits an operator satisfactorily to discriminate and deal with radar data symbols on his display." (p. 120) Conditions: Four observers. Head rest removed. Display rate = 3.2 seconds. Intensification time = 14 microseconds. Tube intensities = low and maximum on bright numbers 2 and 3, and medium and maximum on a standard tube. Room illumination (utilizing fixtures) = 0.6 and 1.0 foot-candles of SAGE blue; and 0.6, 1.0, 6, and 15 foot-candles of both commercial blue and white light. Of all combinations of variables, "certain . . . conditions were omitted because of time limitations." (p. 122) Results: "As usual, more time is required to perform the task under high levels of room illumination. At the lowest level there are no differences among the illuminants. At 1 foot-candle, SAGE blue has a small advantage. At higher levels the differences between commercial blue and white are not consistent . . . ." (p. 123)

15. O - Comparison of three sources for room illumination, using tipped consoles for the discrimination of radar data. Purpose: "(C)ompare the three qualities of illumination, remedying certain defects in the previous (N) study." (p. 123) Conditions: Nine observers. "The . . . consoles were tipped up so that their faces were five degrees from vertical, and hoods were placed above the display areas. This arrangement . . . approximated the conditions recommended for . . . SAGE-II . . . . The light fixtures were directly over the console shelves, and no light baffles were used between consoles." (p. 123) Room illumination = 0.1, 0.6, 3, and 15 foot-candles of commercial blue and white; and 0.1, 0.6, and 3 foot-candles of SAGE blue light from fixtures; sometimes supplemented by the bare ceiling mode of lighting. Display rate = 3.2 seconds. Intensification time = 14 microseconds. Tube intensities = maximum on the standard, medium on the bright number 2, and maximum on the bright number 3 tube. "The program and procedure were as . . . for the previous experiment." (p. 123) However, all combinations of variables were tested. Results: "The new angle of the tube face, permitting little light to strike (it), permits good performance under all illuminations. The data show that SAGE blue light produces the best operator performance, and that commercial blue and white are about equal . . . Differences among the sources . . . increase as illumination increases. . . (p. 125) The effects of the other variables are the expected ones . . . (p. 127) '(R)oom illumination', in the experiment with normal consoles, may be considered to be equivalent to 'light incident on the implosion shield', and the data may be combined with those obtained with tipped consoles." (p. 128)

Results: "While the experimental data (seem to) show that SAGE blue is superior to white light (understandable, since the blue and yellow filters, on the lights and implosion shield, respectively, are designed to exclude light from the tube face), the differences are not very great when only small amounts of light are allowed to strike the tube face." (p. 130) Further, "it is necessary to consider all possible ways in which room light may degrade legibility. It is assumed that legibility decreases with background luminance. . . (which), in turn, is a function of three factors: reflections from the implosion shield, reflections from the tube face, and excitation of the phosphor. . . (R)elationships imply a rather delicate balance of the constants: relative to white light, commercial blue apparently excites the phosphor sufficiently to cancel the advantage of less reflected light, but with SAGE blue the increased phosphor excitation is less than the reflected light." (p. 129-130) Concerning the test criteria, "(p)ositive correlations were found between speed scores and accuracy scores. Since the speed (time to scan the matrix) measure is more sensitive than the accuracy measures, it is used as the principal datum in reporting the results . . . No statistical tests of significance (with one exception---H) were performed on these data . . . on the grounds that, in 'applied' experiments such as these, statistical significance is not sufficient to establish the importance, to actual system performance, of small differences." (p. 88) In general, the following conclusions were drawn:

1. "The data . . . should be useful to persons designing new display systems or preparing specifications for improving existing (including both SAGE-I and SAGE-II) displays." (p. 130)
2. "Legibility was found to be best for: the Bright tube, high tube intensities, SAGE blue room illumination, fast display rates, long intensification times, and large characters. However, almost all of these . . . were expected; it is the interactions among them (as seen by individual experiment in the previous section) that must be considered." (p. 130)
3. "(R)esults reported here are valid only for the conditions and ranges tested. For example, if the power supply or implosion shield were changed, the legibility functions might be quite different." (p. 130)
4. "While SAGE blue has consistently produced the best legibility scores, white light may be considered (because of economic reasons) for rooms containing SAGE-type displays, provided that other display conditions are optimized." (p. 130)

5. "Ability to read printed material and perform other non-CRT-oriented tasks is not necessarily constant for equal levels of room illumination of different qualities. Blue light probably does not permit as good visual acuity as does white light, but the published data are contradictory on this point. A study of the legibility of typical printed material under the alternative illuminants would be valuable." (p. 130)
6. "(D)ifferences in legibility scores . . . (could not) be related to differences in visual acuity . . . ." (p. 131) The experimenters hypothesized that "level of aspiration" may have been more responsible for the individual differences found.
7. "(S)ome observers expressed a preference for low levels of illumination, but others favored high levels. The data show that low levels produce better legibility for all observers regardless of their subjective opinions. The same is true for differences among colors of room illumination." (p. 131)
8. "(N)o observer . . . ever reported any degree of sickness or discomfort due to the SAGE arrangements, even after prolonged observation." (p. 131)

"Several problems (including that noted in 5. above) . . . point to the need for further research or special technical information. These areas include: details of the relationship between intensification time and display rate, characteristics of phosphors, design of symbols for the tube matrix (especially with respect to stroke width), and methods for measuring tube intensity." (p. 131)

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2156 Harris-1956

Harris, W.P., Green, B.F., Wilson, E.A., and
Liaudansky, L.H.
Lincoln Lab., Mass. Inst. of Tech., Lexington
THE DESIGN OF CHARACTERS FOR THE CHARACTRON
Technical rept. no. 117, 8 May 56, 25p.
AD-101 142

<u>Problem</u>: On the basis of experimentation, design a set of numerals, alphabetic (upper case) characters, and special symbols "that would have maximum legibility on the Charactron display. . . (Also,) interpret confusions among characters to provide tentative hypotheses for a theory of legibility." (appendix)

<u>Procedure</u>: "Special cathode-ray tubes called Charactrons are used in the SAGE System to display information to the operators. This report describes several studies concerned with the design of characters for use on these displays. . . Legibility was evaluated . . . by noting how easily a character could be identified and how seldom it was confused with other characters in the set. . . The studies reported . . . (were) concerned only with the shapes of the characters. The parameters of size, stroke width and height-width ratio were held constant. The characters, as they appeared on the display, were about 0.120 (inches) high, . . . . They had a nominal stroke width of 0.010 (inches), but the apparent stroke width was more nearly 0.020 (inches) because of light-scattering in the phosphor. The height-width ratio was 4 (to) 3 for letters and numbers, and 1 (to) 1 for symbols. The literature indicates that . . . stroke widths for bright numerals on a dark ground should be slightly thinner . . . ." (p. 1) The author notes that "(s)everal designs for numerals (were)

available, including BERGER's, MACKWORTH's, the . . . AND-10400, the LEROY lettering set and the . . . AMEL. . . MACKWORTH's design was chosen as a starting point . . . ." (p. 3) Thus, in Experiment 1, five subjects viewed the ten MACKWORTH numerals, one at a time, in a Charactron-type display. Exposure time was 0.25 seconds per character, but at various (five different) delay (after the character was written on the screen) times. Characters were 0.25 inches high and viewed from 60 inches. This simulated the Charactron display wherein characters are 0.120 inches high and viewed from approximately 29 inches. "The fixed conditions of the experiment were chosen to represent the poorest expected in practice. The purpose (being) . . . to raise the subject's error rate to a level that would give clearcut effects in a short experiment. The level of ambient illumination was high: 0.5 (foot-candles) rather than the optimum level of about 0.1 (foot-candles). The ambient light was white (incandescent) . . . (rather than blue fluorescent) . . . ." (p. 4) In Experiment 2, 21 symbols were viewed by 10 subjects. "Some of (the symbols were) line figures, like letters and numbers, while others (had) solid areas. Some (were) pictorial; others (were) abstract designs." (p. 8) Experimental conditions were as in Experiment 1. After a complete set of characters for the Charactron was designed (on the basis of the above experiments, and presumably others for the alphabetic set), the set was evaluated in experimentation not detailed in this report, and changes were made.

Result: Confusion data between numerals was shown in the results of Experiment 1. The following were predominant confusions (stimulus-response): 2-7, 3-5, 5-3, 6-4, 7-2, and 9-7. In Experiment 2, "(t)he over-all error rate (was) 30.0 per cent, which (was) much higher than the 13.2 per cent error rate in Experiment 1 . . . . The difference may (have been) due in part to the increased number of alternative responses. . . (p. 9) Variations of a single geometric form were often confused, while pictorial symbols were more legible than geometric symbols. . . (p. 21) (The) confusion matrix for special symbols in Experiment 2 .". . (p. 10) showed the following predominant confusions (stimulus-response): open square-ring, diamond-ring, diamond-O bar, O bar-diamond, bull's eye-O bar, bull's eye-checker, bull's eye-large dot, large dot-bull's eye, double cross-bull's eye, double cross-large dot, double cross-star, star-double cross, plus-star, solid up-star, open down-bull's eye, solid down-propeller, and propeller-open down. From the evaluation of the complete set of 63 characters designed for the Charactron, "very few important confusions were noted." (p. 21) However, from the confusion matrix chart, these were (stimulus-response) as follows: H-N, I-1, Q-O, Z-2, 1-I, 2-Z, 5-S, 6-rocket, 8-B, block-square, clip-3, cross-plus, key-flag, plus-cross, plus-dot, dot-star, dot-ring, star-dot, ring-dot, O bar-ball, plane-K, radar-rocket, and rocket-A. The total set of Charactron Characters (M.I.T. Mod X) developed was as follows: A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U, V, W, X, Y, Z, 1, 2, 3, 4, 5, 6, 7, 8, 9, arch, wedge, table, block, clip, square, triple, double, cross, key, plus, dash, dot, star, ring, up, down, ball, flag, gun, O-bar, plane, post, radar, rocket, and blank. In reference to the "tentative hypotheses for a theory of legibility," the following is the only

reference in the text alluding to them/it: "From a theoretical standpoint, it is clear that any kind of difference between members of a confused pair can be accounted for by invoking an imprecise theory of features in conjunction with an arbitrary assignment of response probability. However, experiments can be designed which will permit a distinction between these variables. From the standpoint of the 'art of high-legibility design,' the analysis is a matter of practical judgment, and the usual remedy of using features that are more distinctive is likely to help in any event." (p. 8)

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3272 Hastings-1956

Hastings, Clinton B.
Texas Highway Department
AN INVESTIGATION OF AVAILABLE MATERIALS AND METHODS FOR PRODUCTION OF BEADED RED STOP SIGNS
Undated, 33p.
Abstract in Highway Research Abstracts, 26:1 (January 1956) 25-26

Abstract: "The adoption of the red stop sign by AASHO prompted the Paint Section of the Materials and Tests Laboratory to investigate the various types of red pigments and varnishes that were available and the methods that could be followed in the production of such signs. Sample quantities of all proposed materials were obtained and two general types of signs were made. Several different procedures were followed employing various pigments and formulations of bead binder. The resulting signs were examined and evaluated. Test results show that:

1. "Care must be exercised in the choice of red pigments, because most of the common red pigments are not satisfactory for exterior exposure. The addition of glass beads often accelerates failure of red pigments on exterior exposure.
2. "When either red or yellow beaded signs are made with a single layer of colored, opaque bead binder, in the manner that the yellow stop signs have been made in the past, then the yellow signs appear several times as brilliant as the red ones. Reflected light from this type of red signs usually is a dull, orange-red color. This single-layer type is relatively less expensive and is easier to make than the second type of sign described later.
3. "A brighter red sign may be made by starting with a white or metallic reflecting layer on which is placed a layer of transparent red, topped off with a layer of clear bead binder and beads. Due to the optical characteristics of the glass beads, improper thickness of the transparent layer will cause dispersion of the reflected light and a reduction in brilliance of the sign; lack of uniform thickness will produce light or dark blotches. Therefore, some accurate means of determining and controlling the thickness of the transparent layer is required. Many of the possible

designs are covered by patents.

"The report discusses the light reflectance of pigments, the effect of light source on color reflectance, relative sensitivity of the human eye to all wave lengths, optics of glass beads, and selection of transparent pigment and binder having satisfactory characteristics." (p. 25-26)

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3372 Herrington-1960

Herrington, C. Gordon
Illinois U., Urbana
DESIGN OF REFLECTORIZED MOTOR VEHICLE LICENSE PLATES
In HIGHWAY RESEARCH BOARD, PROCEEDINGS OF THE THIRTY-NINTH ANNUAL MEETING, 1960, Herbert P. Orland, Editor, (Washington, D.C., National Academy of Sciences-National Research Council Publication 773, 1960), Vol 39, p. 441-466, 17 refs.

Problem: Investigate "the basic factors concerning the legibility of reflectorized license plates and evaluate each of these components for an optimum plate design." (p. 441) The experiment is designed to provide for optimum legibility in daytime and at night under actual traffic conditions. "The factors given extensive analysis . . . were (a) . . . types of reflective materials; (b) the effects of reflectorizing the legend, the background, or both portions of the plate; (c) contrast direction; (d) thickness of stroke; (e) character spacing; (f) use of . . . borders; and (g) various color combinations." (p. 441)

Procedure: "Ninety-seven specimen license plates of various designs were viewed by 30 observers with a specially designed apparatus which simulated actual nighttime driving conditions. The data were analyzed . . . (for) reliability of the results and significance of interactions between variables. . . All of the experiments . . . deal(t) with a relative . . . and not . . . a specific legibility distance. There is no inference that identical distances would be found under actual conditions." (p. 441) The following parameters were varied as shown:

1. Types of reflective materials: flat sheeting, exposed lens sheeting, beads on paint, semi-gloss paint, and aluminum paint.
2. Systems of reflectorization: background only reflectorization, legend only reflectorization, and both background and legend reflectorization.
3. Contrast direction: dark legend on light background, and light legend on dark background.
4. Stroke-width of characters: 8/32-, 10/32-, 12/32-, and 14/32-inch strokes, corresponding to height/stroke-width ratios of 12.0 to 1, 9.6 to 1, 8.0 to 1, and 6.8 to 1, respectively.
5. Spacing of characters: 1-1/2 and 2-1/2 inches, center-to-center.

6. Use of borders: with and without borders.
7. Color combinations: "The colors used were the flat sheeting colors." (p. 458) The color combinations tested were as follows: light legends on dark bakcgrounds; white on orange, yellow on red, yellow on green, white on red, white on green, orange on green, orange on blue, yellow on blue, white on blue, orange on black, and white on black; dark legends on light backgrounds; orange on white, red on yellow, red on white, green on yellow, green on orange, green on white, blue on yellow, blue on orange, black on yellow, black on white, and blue on white.

"Each plate had 4 numbers as the copy or legend. . . The number 1 was omitted . . . (p. 444) For uniformity, all numbers were 3 (inches) high and were . . . Bureau of Public Roads Standard Number SERIES B (modified) . . . All plates were the standard 6- by 12-(inch) size with rounded corners. . . (p. 445) This study . . . was performed in two phases . . . The first group . . . was designed to study . . . the following . . .: 1. Stroke width of characters. 2. Various types of reflecting materials. 3. Systems of reflectorization. 4. Contrast direction. The second group . . . was concerned with the following . . .: 1. Interaction between stroke width and spacing of digits. 2. Character spacing. 3. Use of borders on plates. 4. Color combinations." (p. 446)

Result: Analysis of variance of phase 1 reflectorized plates yielded the following statistically significant variations: stroke-width (5 percent level of confidence), contrast direction (1 percent), type of material (5 percent), system of reflectorization (1 percent), system of reflectorization and contrast direction interaction (1 percent), and contrast direction and stroke-width interaction (1 percent). For the phase 1 nonreflectorized plates, the following variations were noted: type of material (5 percent), and contrast direction (1 percent). The phase 2 tests yielded the following results, in terms of the variables studied: interaction between stroke-width and spacing of digits---"(t)he use of an inappropriate stroke width at a narrow spacing ha(d) a greater effect on legibility than it (did) at a larger spacing.". .; (p. 456) character spacing---"(f)or plates with an opaque legend on a white reflectorized background, the relationship between spacing and legibility distance (was) linear . . ., however, . . . in the smaller spacing range. . . (i)ncreases in spacing . . . cause disproportionate increases in legibility distance.". .; (p. 456) use of borders on plates---"(a) 3/16-(inch) opaque border on a plate with a white reflectorized background had no significant effect on legibility distance. . . (, also t)he legibility distance of an opaque plate with a white reflectorized legend and 1/8-(inch) border was not significantly different from a similar plate with no border . . ."; (p. 457) and color combinations---the following table of color identification shows the legend and background colors, the percentage of time identified correctly and the percentage confusion with other colors:

| | color | percentage of time identified correctly | confused with (percent) |
|---|---|---|---|
| legends: | black | 84.0 | - - - |
| | blue | 16.4 | black (54.5) |
| | red | 63.0 | black (13), blue (6.5) |
| | green | 27.0 | black (32), blue (18) |
| | orange | 31.8 | white (40), red (17) |
| | yellow | 24.7 | white (65) |
| | white | 54.0 | yellow (32) |
| back-grounds: | black | 87.0 | red (12) |
| | blue | 78.5 | green (20) |
| | red | 93.0 | orange (7) |
| | green | 98.8 | - - - |
| | orange | 88.0 | red (10) |
| | yellow | 66.0 | orange (24), white (10) |
| | white | 94.0 | yellow (4) |

(above from p. 460)

"Some elements of reflectorized license plate design which are not directly concerned with legibility must be considered in the design of a license plate . . . ." (p. 461) These include (1) visibility, (2) durability, (3) cost, (4) method of plate distribution, (5) expected service life of the plate, (6) availability of the materials, (7) manufacturing restrictions, (8) ease of cleaning, and (9) all-weather performance.

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2157 Hitt-1960

Hitt, W.D., Schutz, H.G., Christner, C.A. and Coffey, J.L.

Battelle Memorial Inst., Columbus, Ohio

DEVELOPMENT OF DESIGN CRITERIA FOR INTELLIGENCE DISPLAY FORMATS

Final rept., 21 Sep 60, 120p., 18 refs.

Contract AF 30(602)-2078

RADC-TR-60-201; AD-245 138

<u>Problem</u> <u>(general)</u>: "(D)evelop design criteria for intelligence display formats to be used in the Samos data-processing sub-system." (p. 1)

<u>Problem</u> <u>(Experiment I. A Comparison of Vertical and Horizontal Arrangements of Alpha-Numeric Material)</u>: "(D)etermine the relative effectiveness of visual displays containing alpha-numeric material displayed in vertical and horizontal arrangements." (p. 1)

<u>Procedure</u> <u>(Experiment I)</u>: "Variables included in the experimental design (see also Coffey-1961) were: types of arrangement of display material, density of material, composition of material, and operator tasks." (p. 1)

<u>Result</u> <u>(Experiment I)</u>: "The major finding . . . was the nonsignificance of the arrangement variable. It was found that, for all practical purposes, the differential effects of vertical

and horizontal arrangement of alpha-numeric materials on operator performance (were) negligible." (p. 1)

Problem (Experiment II. An Evaluation of Formats for Graphic Trend Displays): "(D)etermine which of three types of trend formats results in superior performance for a task requiring the subject to make complex decisions." (p. 1)

Procedure (Experiment II): "Three commonly used formats were included in the study: line type, vertical-bar type, and horizontal-bar type. Two secondary independent variables were: number of time points and amount of missing data." (p. 1)

Result (Experiment II): "Results . . . indicate that preference should be given to line-type graphs, followed closely by the vertical-bar type. A secondary finding was that irrelevant points and missing data on graphic trend displays represent important factors in the degradation of operator performance." (p. 1)

Problem (Experiment III. An Evaluation of Methods for Presentation of Graphic Multiple Trends): "(D)etermine the effect of multiple-line versus multiple-graph presentation of trend-type displays on operator performance." (p. 2)

Procedure (Experiment III): "Four types of lines having low confusability were determined experimentally from a sample of 25 lines. The primary variable was single-graph, multiple-line presentation versus multiple-graph, single-line presentation. Other variables included in this study were: number of lines, degree of confusion among lines, coding of lines, and two operator tasks: point-reading and comparing." (p. 2)

Result (Experiment III): "(F)or the point-reading task, either type of display is acceptable, but for the comparing task, the multiple-line display (was) much superior to the multiple-graph display. Moreover, the use of color coding for the graph lines tended to improve performance slightly." (p. 2)

Problem (Experiment IV. An Evaluation of Five Different Visual Coding Methods): "(A)scertain the relative effectiveness of selected abstract coding methods, based upon their effects on various operator tasks." (p. 2)

Procedure (Experiment IV): "Five different coding methods were selected: numeral, letter, geometric shape, color, and configuration. Secondary variables included in the study were target density, number of coding levels, and operator tasks." (p. 2)

Result (Experiment IV): "(N)umeral coding and color coding (were) the two superior coding methods. If greater emphasis is to be placed on identifying symbols, numeral coding is superior to color coding. No significant differences were found, however, between numeral coding and color coding for the remaining operator tasks: locating, counting, comparing,

and verifying." (p. 2)

Problem (Experiment V. An Evaluation of the Effect of Selected Combinations of Target and Background Coding on Map-Reading Performance): "(D)etermine the relative effectiveness of selected target/background coding combinations." (p. 2)

Procedure (Experiment V): "Three target codes were: color, number, and enclosed shape. Five types of background were: all white, solid gray, five shades of gray, five pastel hues, and five different patterns. These target/background coding combinations were evaluated under eight different complexity conditions and for five different operator tasks." (p. 2-3)

Result (Experiment V): "The major findings . . . were: (1) no significant differences . . . in background coding, (2) numeral coding (was) superior for the 'identifying' task, and (3) color coding (was) superior for the 'locating' and 'counting' tasks." (p. 3)

Result (general): The following problem areas, delineated prior to experimentation, are of interest to those concerned with a break-down of the problem areas in the legibility of alpha-numeric characters and similar special symbols:

| display parameters | variables to consider |
|---|---|
| format . . . . . . . . | arrangement of categories (alpha-numeric and trend displays) |
| format . . . . . . . . | use of color (alpha-numeric and cartographic displays) |
| format . . . . . . . . | black on white versus white on black (all displays) |
| format . . . . . . . . | size of display (all displays) |
| format . . . . . . . . | ambient/display lighting ratio (all displays) |
| format . . . . . . . . | line graph versus bar graph (trend displays) |
| format . . . . . . . . | number of trends (trend displays) |
| format . . . . . . . . | degree of pictorial reality (cartographic displays) |
| format . . . . . . . . | area covered (cartographic displays) |
| format . . . . . . . . | use of texture (cartographic displays) |
| format . . . . . . . . | use of elevation (cartographic displays) |
| format . . . . . . . . | mosaic or single map (cartographic displays) |
| format . . . . . . . . | scale (cartographic displays) |
| density . . . . . . . . | number of categories (alpha-numeric displays) |
| density . . . . . . . . | total number of letters and numbers (alpha-numeric displays) |
| density . . . . . . . . | amount of data per unit area (alpha-numeric displays) |
| density . . . . . . . . | "word" size (alpha-numeric displays) |

| display parameters | variables to consider (continued) |
|---|---|
| density . . . . . . . . . | number of trend figures (trend displays) |
| density . . . . . . . . . | amount on each figure (trend displays) |
| density . . . . . . . . . | amount of detail of geographic nature (cartographic displays) |
| density . . . . . . . . . | number of names of cities, etc. (cartographic displays) |
| density . . . . . . . . . | number of symbols (cartographic displays) |
| number of categories . . | data are given for how many categories (alpha-numeric displays) |
| number of categories . . | number of graphs (trend displays) |
| number of categories . . | number of different lines on graph (trend displays) |
| number of categories . . | types of information (cartographic displays) |
| number of categories . . | how many types of symbols (cartographic displays) |
| coding dimensions . . . . | descriptive phrases versus symbols for categories (alpha-numeric displays) |
| coding dimensions . . . . | what coding systems for symbols (alpha-numeric displays) |
| coding dimensions . . . . | families of symbols (alpha-numeric and cartographic displays) |
| coding dimensions . . . . | multidimensional coding (alpha-numeric and trend displays) |
| coding dimensions . . . . | use of colored symbols (alpha-numeric and cartographic displays) |
| coding dimensions . . . . | association characteristics (alpha-numeric and trend displays) |
| coding dimensions . . . . | what symbols are used (trend displays) |
| coding dimensions . . . . | how are symbols organized (trend displays) |
| coding dimensions . . . . | use of color coding (trend displays) |
| coding dimensions . . . . | how are categories coded (cartographic displays) |
| coding dimensions . . . . | what dimensions (e.g size, shape) for each information category (cartographic displays) |
| coding dimensions . . . . | degree of reality in code-association characteristics (cartographic displays) |
| rate of change . . . . . . | change of categories (alpha-numeric displays) |
| rate of change . . . . . . | change of all data for categories (alpha-numeric displays) |
| rate of change . . . . . . | change of particular data for categories (alpha-numeric displays) |
| rate of change . . . . . . | number of time intervals (trend displays) |
| rate of change . . . . . . | change of present time condition (trend displays) |
| rate of change . . . . . . | rate of change of new parameter (trend displays) |
| rate of change . . . . . . | number of different maps per unit time (cartographic displays) |

| display parameters | variables to consider (continued) |
|---|---|
| rate of change . . . . . . | rate of updating symbols on map (cartographic displays) |

(above from p. 10-11)

In addition, the following general discussion and conclusions were pertinent:

1. "(D)esign recommendations based on only main effects can be misleading. In most of the . . . described experiments, the results were qualified by the various interactions. Naturally, if such interactions are so small that they have little practical significance - even though they are statistically significant - then the designer need not be burdened with such findings. (sic) When such interactions are important in a practical sense, however, it is essential that recommendations be qualified in accordance with these findings." (p. 116)
2. "(S)ignificant interactions were found between display conditions and operator tasks. . . Furthermore, . . . it is important to determine . . . whether or not these task factors are representative of the real-world data-processing operations under study. It would then be possible to make recommendations concerning display parameters according to the relative importance of the various tasks." (p. 116)
3. "A review of the literature emphasize(d) the need for more standardized . . . conditions for the study of visual displays. It is a relatively easy task to find studies . . . that report contradictory results. By reviewing these . . . in detail, however, it might be found that they differed in: subject tasks, specification of . . . environment, experimental procedures, and environmental conditions, as well as characteristics of subjects." (p. 116)
4. "To assist the individuals responsible for the design of visual displays, an extremely worthwhile goal would be to develop a detailed, up-to-date handbook on 'Design Criteria for Visual Displays' . . . . Much information is already available . . . . If . . . collected and integrated, . . . it would serve as an excellent foundation for a visual-display handbook, as well as give direction to future work on visual displays." (p. 117)

Recommendations for further research, as "logical extensions of the experiments" (p. 117) here, could be in the following areas: (1) Methods of Grouping Alpha-Numeric Data. (2) Coding Single Categories of Information. (3) Two-Dimensional Abstract Coding. (4) Realism in Target Coding.

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2161 Hodge-1962

Hodge, David C.

Rochester U., N. Y.

LEGIBILITY OF A UNIFORM-STROKEWIDTH ALPHABET: I.
RELATIVE LEGIBILITY OF UPPER AND LOWER CASE LETTERS

Journal of Engineering Psychology, 1:1 (January 1962) 34-46, refs.

Problem: Compare the legibility of black upper- and lower-case letters read individually against a white background under a high level of illumination.

Procedure: Fifteen college students, ranging in age from 16 to 44 and demonstrating 20/20 binocular acuity, each viewed, in a highly illuminated enclosure, at distances ranging down from 300 centimeters (250 centimeters for lower case), seven LEROY (number 3240-350 CL) upper- and lower-case alphabets. Height to stroke-width ratios varied between 3.7:1 and 14.6:1. A modified method of limits was used in determining legibility threshold distance.

Result: Capital letters were recognized at a significantly greater distance than lower-case. Optimum height to stroke-width ratio was 5.6:1 for capitals and 4.6:1 for lower case. Lower-case letters appear to be appropriate for use in some visual displays since recognition distance for the optimum lower case, height to stroke-width ratio was more than twice the standard instrument panel viewing distance of 28 inches, but further research is indicated. Examination of letter identification confusion errors suggests that there is little capitals/lower-case overlap. Practical applications of confusion error data were suggested, and a legibility frequency table for capital and lower-case letters was presented as shown below (most legible to the left):

L A J Z T U E P S M V N F W R D C X I K Y B O G H Q

m p d b c u y v w h n z q k g r x j o s f e i t a l

(Font shown here was not that used in experiment.) Pairs of letters underlined were equally legible.

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3373 Hodge-1963

Hodge, David C.

Rochester U., N. Y.

LEGIBILITY OF A UNIFORM-STROKEWIDTH ALPHABET
II. SOME FACTORS AFFECTING THE LEGIBILITY OF WORDS

Journal of Engineering Psychology, 2:2 (April 1963) 55-67, 15 refs.

Based on Ph. D. Dissertation

Problem: Determine, under varying exposure lengths, letter spacings, and height/strokewidth ratios, "the relative legibility of words made up of black upper, lower, and mixed upper and lower case letters of a uniform-strokewidth alphabet, as might be used on a white background under a high luminance condition on instrument panels (e.g. a bank of annunciators). . . In addition, the effect on . . . legibility of . . . (the interaction between) the amount of spacing . . . and the (height/strokewidth) ratio . . . were investigated." (p. 56) From previous investigation, the possibility is suggested that "words in other than all upper case letters might be more appropriate for use in visual displays . . . ." (p. 56)

Procedure: "Sixty (subjects---18 female and 42 male university students and staff, age 17 to 41 years, with a mean age of 20.3, having normal, or corrected to normal, vision, and with English as their native language---assigned at random to the six treatment groups, 10 subjects per group) read (at 28 inches) groups of (eight) unrelated five-letter words (a total of eighty were selected from the 1000 most common as listed by Thorndike and Lorge) during exposures of varying duration (0.30, 0.55, 0.80, 1.05, and 1.30 seconds in a box apparatus illuminated with 13 foot-lamberts on the test card), and after each exposure reported (verbally) what they had been able to read. The measure of legibility was the mean number of correct responses per (subject) per condition." (p. 66) Conditions were as follows: (1) upper (10 cards), lower (10 cards), and mixed (first letter capitalized) upper and lower case (10 cards), (2) spacing between letters = 25, 50, and 75 percent of mean letter width, and (3) height/strokewidth ratio = 5.6:1 and 10.2:1. "(S)ubjects . . . (p. 56) (were) tested under all three levels of the cases variable, and under one of the six possible combinations of the spacing and ratios variables. . . (p. 57) The words were drawn (in India ink on tracing paper mounted on white Bristol board cards 4.0 inches wide by 3.25 inches high) with the Keuffel and Esser LEROY lettering . . . (p. 57) template number 3240-140CL (upper case letters similar to the standard MS-33558---formerly AND-10400); upper and tall lower case letters were thus about 0.14 (inches) in height. The two (height/strokewidth) ratios were drawn by . . . pen number 2 giving . . . 5.6/1, and pen number 00 giving . . . 10.2/1." (p. 58) The arrangement of words on the cards was in two columns of four each with the left-hand margins of words in the first and second columns 0.75 and 2.5 inches, respectively, from the left side of the board. Each of the words had its base 0.7 inches from the top of the card or the base of the word above.

Result: The following results were seen:

1. "The finding . . . that words printed in all upper case letters were significantly superior to those in mixed, or lower, cases was somewhat unexpected, . . . ." (p. 64) However, by contrast to the situation reported herein, in which "the task . . . was designed to incorporate the visual skills used in an actual instrument panel viewing situation, . . . (p. 65) (an) important aspect of (reading) the extended passage is the context . . . and the meaning of the material may be understood

without the necessity for reading every single word." (p. 64)

2. "(T)he 75 percent spacing condition was the most legible one, and . . . the functions for spacing at the three levels of cases have about equivalent slopes. No explanation can be found for this discrepancy in results, either . . . ." (p. 65-66)
3. "(T)he 5.6/1 ratio was more legible . . . . This result was predicted . . . somewhat paradoxical(ly) . . . since the task used . . . earlier . . . was . . . considerably different . . . ." (p. 66)
4. "The finding of no interaction between the (height/strokewidth) ratio variable and the two other independent variables (not including the different exposure times) suggests that in future . . . research . . . (this) variable need not be manipulated." (p. 66)

Thus, "(t)he data were interpreted . . . that, for optimal performance, single-word (sic) instrument panel labels should be printed in all upper case letters with spacing between letters of at least 75 percent of mean letter width; and that a (height/strokewidth) ratio of 5.6/1 is better than 10.2/1." (p. 66)

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2162 Hogg-1957

Hogg, Doreen

McGill U. (Canada)

EFFECTS OF LETTER POSITION ON RECOGNITION

M.A. Thesis, Aug 57, 26 p., 11 refs.

Problem: This study is designed to answer some of the following questions:

1. "Does the (neuro-muscular, ocular coordination) mechanism operate in the same way when stimuli are displayed on both sides of the fixation point simultaneously?
2. "What would be the effect of the introduction of gaps in the letter formation, or the effect of the introduction of forms?
3. "Do changes in spacing affect the operation of the mechanism?
4. "What, if any, is the effect of educational level?" (p. 4)

Procedure: "The stimulus material for all experiments consisted of 13 upper case letters and eight geometric forms. . . arranged in a square in the centre of 3 (inch) by 5 (inch) white cards so that the midpoint of the letters and forms was equidistant from the fixation point. The letters were TYPEWRITTEN with an electric typewriter. The recognition threshold of each letter had been previously determined, and the letters were rotated so that letters of equal difficulty appeared an equal number of times in each position. The geometric forms, which were slightly larger than the letters, were stencilled on the cards. Each form appeared in each position an equal number of times." (p. 5) A total of 104 Army personnel and college student subjects participated in three experiments, in which they viewed and reported on stimuli in a Gerbrands Harvard tachistoscope at 20 and 30

milliseconds. "The object of the first experiment was to see whether the order of report was affected (1) by the introduction of geometric forms and blank spaces in the letter series (2) by using geometric forms alone as stimulus material. (3) by increasing the horizontal distance between the letters. . . (p. 6) In the second experiment, . . . the same stimulus materials were presented in the same sequence as . . . in the first experiment, but the subjects were . . . college students (vs. Army personnel)." (p. 10) Since the first two experiments contained a preponderance of letters, this "may have induced a 'set' to respond to forms in the same way as letters." (p. 12) The third experiment "was an attempt to isolate any such effect." (p. 12)

Result: "(T)he accuracy with which stimuli in different positions (were) recognized (was) affected by the stimulus arrangement, the context in which they (were) presented, and the educational level (sic) of the subjects. . . (T)hese findings are, for the most part, inconsistent with earlier, relatively specific, interpretations . . . . An explanation is proposed which attributes the phenomenon to complex interactions among the individual stimuli. It is suggested that these interactions are the result of a process of selective attention through many years of reading experience." (p. 21) Specifically, "the results are not entirely compatible with Heron's interpretation. In the first place, the phenomenon which he describes (the fact that letters exposed in a square are reported from upper left to lower right) is only obtained when the letter groups subtend the same visual angle as the groups he used. . . In addition, . . . (the) results . . . (were not) specific to alphabetical material. . . It seems that when the order of report is disrupted (as by blank spaces or geometric forms), letters to the right of fixation are more often reported than those to the left." (p. 16-17) Otherwise, it follows "the order in which it would normally be read, that is, from upper left to lower right. . . (p. 18) When the period of time for which the stimuli were presented was shortened (from 30 to 20 milliseconds), the effect of letter position on recognition disappeared. Letters in all four positions were recognized with equal ease. That is, this might be a case in which the stimulus was strong enough to excite the cell assemblies corresponding to the individual letters, but not strong enough to excite the pathways responsible for the ordering process." (p. 20)

Note: Upon review, the above work appears to be reported on later by Doreen Kimura (Kimura-1959, following). It is possible that the same experimenter is involved, with the above having been done prior to Mrs. Kimura's marriage.

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2164

Hollingworth-1913

Hollingworth, Harry
ADVERTISING AND SELLING, PRINCIPLES OF APPEAL AND RESPONSE
New York, D. Appleton and Co., 1913, 314 p.

Problem: "(F)ormulate and systematize those facts and laws which relate to the processes of appeal and response in the selling and advertising of goods, and . . . undertake investigations which might result in the discovery of new facts and principles of both practical and scientific interest." (p. v)

Procedure: "(F)our distinct aims . . ." (p. v) have been utilized:

1. "To sort out, from the general body of psychological doctrine, such principles as underlie the mental processes involved in creating, presenting and reacting to appeals which are presented in the form of advertisements, arguments, selling talks, etc; to state these in systematic form for convenient acquisition and reference by the active and prosperous business man.
2. "To examine such various methods, media and devices as have proven clearly successful or unsuccessful in known circumstances, places, and with different commodities, and to deduce and formulate any principles revealed by such comparative study.
3. "To carry on, in a cooperative way, new experiments and investigations, by exact scientific methods, and with the definite intention of helping to render the technique of the laboratory more and more serviceable in handling the practical problems of daily business life.
4. "To devise accurate and reliable methods of testing beforehand the probable value of appeals which are intended for actual use in advertising and selling, (a) by more exact study of the known principles of appeal and response and their applications in business transactions, and (b) by a comparison of laboratory tests with keyed results produced by the appeals in business campaigns." (p. v-vi)

The following table of contents shows the scope of the book:

XII. The fourth task: provoking the response.

XIII. Instincts, their nature and strength.

XIV. The relative strength of the chief instincts and interests.

XV. Sex and class differences of interest to business men.

Result: The following statements concern typography, environment, and the legibility of characters:

1. (analysis of advertising types) - The psychology of the classified advertisement involves ". . . typography---the laws of reading, spacing, position, cataloging, color, legibility of type, etc." (p. 33) The psychology of the publicity advertisement ". . . is usually mechanical---utilizing the principles of size and contrast." (p. 35) Both of the above types of factors are involved in the display advertisement.
2. (media) - The eight classes of advertising media, ". . . according to psychological character and situation" (p. 38) are as follows:
    a. Newspapers, magazines, periodicals, and trade journals.
    b. Circulars, hand bills, posters, bulletin boards, electric signs, and placards and signs in street cars.
    c. Size, form, decoration, color, and illumination of store, comfortable service, waiting chairs, courteous attendance, etc.
    d. Printed and stamped novelties, as lead pencils, paper weights, note books, calendars, knives, rulers, tapes, toys, puzzles, etc.
    e. Registers, directories, theater programs, etc. (resembles b. above).
    f. Delivery wagons, street banners, floats, etc. (resembles c. above).
    g. Samples, catalogues, agents, and traveling men.
    h. The personal communication, form letter, and "follow-up" literature of booklet and pamphlet.
3. (the first task: catching the attention) - "(T)he range of attention is limited. . . (to) five units that can be encompassed in a single act of attention." (p. 57-58) This may include five (or six) dots, letters, words, or phrases, providing the latter "are familiar enough to be perceived as units. . . Nine to sixteen words make a clear and easily read sentence. . . (G)ood headlines will seldom be found with more than nine and usually not more than five words." (p. 58-59)
4. (intensity of the stimulus) - "The intense lights of an electric sign, the brilliant colors of a billboard placard may force us to look in their direction. But they may force us just as quickly to look away again." (p. 62)
5. (magnitude of the stimulus) - "Scott's general conclusion (from an experiment on the size, as measured by fraction of a page, of an advertisement) is: 'The attention and memory value of an advertisement increases as the size of the advertisement increases, and the increase of value is greater than the increase in the amount of space used.'" (p. 65) However, the response does not necessarily match that. Figures derived by the author "suggest a more or less definite law of increase under such circumstances, namely: the number of inquiries tends to increase as the square root of the amount of space used." (p. 67)

6. (magnitude of the stimulus - typography) - "Gale found progressive increase in attention value with increase in size of type from two to six millimeters." (p. 72) Scott, in a speed of reading test, found that a "HEAVY face" was read faster and with fewer errors than a "LIGHT face" type. "The writer would . . . be inclined to stress the futility of mere size as an effective advertising device." (p. 73-74)
7. (contrast) - "(A) striking difference between foreground and background has strong attention value, and black on white, blue on yellow, red on green are the most striking combinations . . . ." (p. 76) As to black-on-white vs. white-on-black, "the principle of irradiation would lead us to expect just the opposite result." (p. 77) However, "we habitually associate dark spaces with objects and light spaces with background . . . ." (p. 78) Thus, "when black letters are seen on white the letters attract attention. But when white letters appear on black, they seem to be merely holes in the object . . . So far as acuity and legibility go there is no difference between the two arrangements." (p. 78)
8. (position) - Gale's experiments indicated that the left-hand side of the page had greater attention value, while Starch's experiments indicated quite the reverse. However, the author indicates that, "in flat surfaces the left side will be found the most favorable, in newspaper pages the outside spaces . . . , while on magazine pages there will be little difference found. . . A second question relating to position concerns the relative value of the top and bottom of the page. . . We tend to find meaning in the top of things . . . We begin to read at the top of the page. Further, in reading, experiments show that the . . . eye does not run along the middle of a printed or written line but rather along a line between the middle of the small letters and the tops of the high ones . . . In fixating a general object . . . there is a constant tendency to fixate the center. . . (p. 82) (I)n Starch's tests, the value of the upper half of pages was (greater) . . . as against . . . the lower half . . . Gale . . . found that the quarter just above the middle was strongest, and the bottom weakest." (p. 83) In preference of pages, Starch found "the outer cover to be twice as effective, and the inside cover to be half again as effective as the ordinary inside pages." (p. 84) In an experiment performed by one of the author's students, the following results were obtained: "1. The value of the front section is almost 50 (percent) better than that of the back section. 2. The best page . . . is . . . next to the reading matter in front. The next best . . . next to the reading matter behind. 3. The front cover and the back cover turn(ed) out to be the poorest . . . of . . . twenty." (p. 86-87) 4. and 5. The front and back pages were of equal value within their respective sections. Strong's results were similar, however (and a much larger publication was used) they showed a definitely higher preference for the covers.
9. (color) - Rice showed the visual acuity of colored lights to be in the following order: To 3/4 meter-candles; white, red, blue, green. 3/4 to 1-1/4 meter-candles; white, red, green, blue; Above 1-1/4 (at least to 8-1/2) meter-candles; red, white, green, blue. Allen, in studying the color preferences of savages, gives the following order: red, yellow, orange, blue, green. Baldwin, with babies, shows the following: red,

blue, white, green, brown. Winch, with English school children, shows: blue, red, yellow (falling lower with increasing age and intelligence), green (rising higher with increasing age and intelligence), white, black. Gordon, on a few subjects using background, shows: on black; red, yellow, green, blue; on white; blue, red, green, yellow. Vassar students showed: blue, red, green, yellow and orange. Wissler's studies on Columbia students showed the following results: male preference; blue, red, violet, green, orange, white, yellow; male dislike; yellow, orange, green, blue, violet, red, white; female preference; red, violet, green and blue, orange and white, yellow; female dislike; orange, blue, green, violet, red and yellow (none disliked white). Other results of Wissler's studies indicated the following: "yellow was preferred more by the younger students than by the older (with age, he concludes, the preferred color passes on down toward the violet end of the spectrum); . . . (p. 100) children and women . . . prefer reds, while men and older women . . . show greater fondness for blues. . . Taking these studies as a group, the following points are to be noted. . . (R)eds and blues stand high for educated people, . . . orange and yellow . . . low. For children and savages just the reverse is the case. Yellow falls in the development of the race and . . . the individual. No very striking sex differences for order are shown, but . . . considerable differences for amount. . . (p. 101) (T)he most saturated colors are preferred." (p. 102)

10. (color and third dimension) - "Brightness is easily taken to mean nearness, while relative dullness suggests distance. . . (T)he spectral series shows an increasing suggestion of distance as we go from red . . . to . . . violet." (p. 103) The latter is caused by chromatic aberration in the human eye.

11. (the second task: holding the attention - complexity) - "Perhaps three elements or units . . . represent the ideal; three arguments or propositions of interest, three figures if (it) takes the form of a picture, three styles or sizes of type, three color masses, etc. . . (O)ne . . . for the focus, one for the field, and one for the margin . . . ." (p. 136)

12. (the use of pointers, curves, arrows, borders and similar lines) - "The border . . . tends to keep the eye within the given area . . . ." (p. 137) All turn the eye "back toward the center of the composition. . . (T)he eye tends to move along lines instead of across them . . . ." (p. 138)

13. (lines - quality) - "(F)actors constituting the quality of a line are: (1) breadth; (2) intensity; (3) texture; (4) color. . . Speaking generally, the following principles hold: The fine gray line suggests delicacy of texture. The fine black line suggests precision and hardness. The broad rough line suggests homeliness and solidity." (p. 142-143)

14. (lines - direction) - "The moderate use of vertical lines conveys a suggestion of simplicity, firmness and dignity, with a certain severe grace. Excess of verticals, however, is likely to give stiffness and rigid formality." (p. 144) Because "(s)ide to side movements are frequent, as in . . . reading, . . . the horizontal is the line of ease, quiescence and repose, almost of languor . . . (p. 146) The diagonal line seems to the observer to be full of action and movement. . . (C)urves are more

pleasing than straight lines, whether the curve be arc, serpentine, loop, spiral or what not. . . (p. 147) giving an atmosphere of grace, pliability, richness, and voluptuousness (sic)." (p. 149)

15. (closed forms) - "The triangle . . . is lively, incisive and delicately balanced. Especially if . . . not resting on its base, it is . . . (p. 149) suggestive of spirit, life and constant motion. . . The square . . . suggests solidity and strength, sturdiness. . . so long as (it) remains on one of its sides. . . (O)n one corner it resolves itself into triangles and conveys . . . delicate balance and liveliness. The oblong . . . (whether an ellipse or rectangle, is) most beautiful . . . (in) the 'golden section' . . . (p. 150) such a relation that the size of the whole is to the size of the larger part as that part is to the smaller (a + b : a :: a : b) . . . ." (p. 151)
16. (principles of design) - Quoting Gordon: "'(T)o gain stability, large masses must be below the center, and this is appropriate when the masses are supposed to be heavy; to gain freedom and buoyancy, masses may lie above the center, and this is appropriate when the masses represent something light.'" (p. 157)
17. (character of colors) - Quoting Gordon: "'Red has been compared to the blare of a trumpet, loud and ringing; it is also known as one of the "warm" colors. . . (p. 158) (Y)ellow . . . is the brightest . . . is joyous and uplifting . . . (p. 159) Green is less exciting than the reds and yellows. . . Blue is . . . suggestive of stillness and depth. . . (p. 160) White stimulates a joyful but serene mood. . . Gray is . . . most sober, quiet and subtle. . .' (p. 161) Black by itself is melancholy and depressing . . . . It stands also for quiet. In combination with other colors . . . makes the impression of great concentration and strength. No other color has more 'character' than black." (p. 162) Color combinations and color balance are also discussed in some detail.
18. (feeling tone of content) - "(I)n selecting type faces, bulk, weight, mass or strength demands heavy, strong, bold faced type, while an appeal to feeling or emotion should be conveyed by means of artistically formed letters, shaded type, with free, flowing or graceful lines." (p. 166-167)
19. (feeling tone and imagination) - "An interesting phenomenon which may . . . become of . . . use to the . . . writer is . . . (synaesthesia). (E.g.) One man on record sees consonants as purplish black, while the vowels vary in color. 'U' is a light dove color, 'e' is pale emerald, 'a' is yellow, etc." (p. 176-177)
20. (legibility - favorable length of printed lines) - "The most comfortable . . ., for ordinary printing, is . . . about three and one-half inches." (p. 181)
21. (legibility - appropriate spacing of letters, words, and lines) - "(T)he space between letters making up a word should be less than the width of the letters themselves, while the space between adjacent words should be greater than either of these two distances. The space between sentences should be somewhat greater still. . . (S)pacing between . . . lines should be somewhat less than the width (height of the letters) of the lines themselves . . . (p. 181) Indentation of paragraphs and even of every other line in the printed matter is found to facilitate the process of reading." (p. 182)

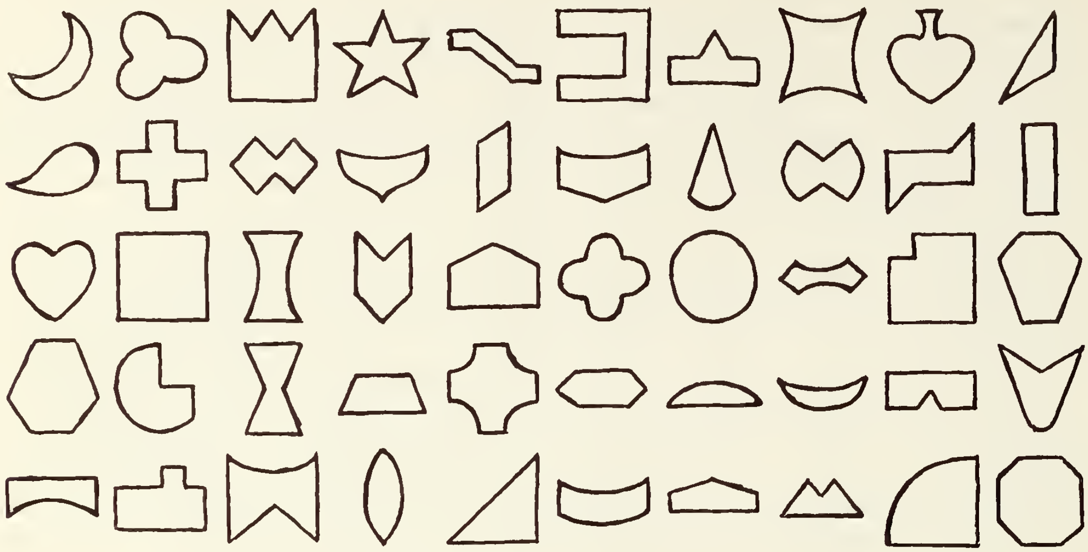
22. (legibility - capitals vs. lower-case) - "(T)he 'lower-case' letters are more easily perceived and read than are capital letters." (p. 184)
23. (legibility - ease of reading) - "(T)oo great a variety of type faces. . . cause(s) lack of unity and organization . . . (Many) different kinds of letters and type faces occurring on a single page call for excessive and uncomfortable changes in . . . rhythmical habits of eye movement . . . ." (p. 185)
24. (legibility - type style) - In testing nine different, 10-point Roman, lower-case styles in a threshold experiment, the following order of legibility was found: NEWS GOTHIC, CUSHING OLD STYLE, CENTURY OLD STYLE, CHELTENHAM WIDE, CENTURY EXPANDED, SCOTCH ROMAN, BULLFINCH, CASLON, and CUSHING MONOTYPE.
25. (legibility - style vs. grouping) - Roethlein, in testing 16 different faces, found legibility "to vary little with the form of the type, but to depend chiefly on the size, width of line, and amount of white space . . . between the letters. The faces differed less when the letters are grouped than they do . . . in isolation." (p. 186) This may be because "much of our reading is done, not by perceiving the separate letters . . .; but . . . recognizing the words as whole . . . 'word forms.'" (p. 187)
26. (legibility - background) - "A maximum brightness difference between background and type makes for easy perception. When colored background or type is used, the same rule holds, for it is not the difference in color as such, but the difference in the brightness values of the colors used . . . ." (p. 187)
27. (principle of connection) - In attempting to impart an idea, "(p)lace first the general class, the purpose or use" (p. 195) that the word should impart "in the moment of need. . . Place next the name . . . which you desire to connect with the need . . . ." (p. 196) A number of further comments are made concerning the "Laws of Original Connection, Principles of Revival," and miscellaneous memory devices.
28. (memorability of different kinds of facts) - "(T)he relative accuracy with which different sorts of facts are reported when direct questions are asked concerning them, runs as follows:" (p. 210)

| | | accuracy (percent) |
|---|---|---|
| a. | mere presence of things | 97 |
| b. | number of people | 65 |
| c. | space relations, form, etc. | 58 |
| d. | condition of objects | 48 |
| e. | order of events | 35 |
| f. | color | 26 |
| g. | size and quantity | 22 |
| h. | sounds | 10 |
| i. | time (duration) | 8 |
| j. | actions (strong attention value but not accurately reported) | - |

(above from p. 210)

Hollingworth-1913

29. (trade marks - geometric forms) - "(T)he relative attention and memory value of different geometric forms . . ." (p. 212) is as follows (left to right and top to bottom):



(above from p. 213)

"The general principle suggested . . . is that those forms are best remembered to which specific names can be given . . . ." (p. 212)

30. (suggestion) - In an experiment with an optical illusion, even though the lines producing the illusion were so faint as not to be perceptible consciously, the illusion was reported on by 17 out of 20 subjects.

The following general statements concern experimentation:

1. "(T)he first requirement of a scientific experiment (curiously neglected in reported tests . . . is) that the only variable factor be that which is being specifically investigated, or that, if other factors vary, this variation be also measured and reckoned with . . . ." (p. 85)
2. "(T)he image power of words depends largely on their feeling tone. An appreciation of this feeling tone must come from literary training rather than from scientific experiment." (p. 173)

* * *

2208 Horton-1960

Horton, David L. and Mecherikoff, Michael
Minnesota U., Minneapolis and Westmont Coll., Santa Barbara, Calif.

LETTER PREFERENCES: RANKING THE ALPHABET

Journal of Applied Psychology, 44:4
(August 1960) 252-253

Problem: "(R)ank order the alphabet . . . according to the appearance of the capital letter." (p. 252)

Procedure: One hundred subjects (all college students---19 males 25 or older, 41 males younger than 25, 5 females 25 or older, and 35 females younger than 25) were asked to list, on a sheet of paper containing a full alphabet in sequence to be used as a check-off list to prevent duplication, the alphabet in the order in which they preferred the appearance of the capital letter.

Result: The following table presents the rankings of the total group, the sub-groups by age and sex, and a previous sample (22 college males):

| | total | | males | | females | | $<$ 25 | | $\geq$ 25 | | previous | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| rank | l* | rank | l | rank | l | rank | l | rank | l | rank | l | rank |
| 1 | B | 7.7 | A | 8.0 | B | 6.1 | B | 7.1 | A | 7.1 | B | 6.7 |
| 2 | S | 8.7 | B | 8.8 | S | 6.6 | S | 8.7 | M | 8.8 | A | 7.7 |
| 3 | A | 8.9 | M | 10.0 | M | 9.2 | A | 9.4 | S | 8.9 | S | 9.6 |
| 4 | M | 9.7 | S | 10.2 | R | 9.6 | M | 9.9 | B | 9.8 | M | 10.6 |
| 5 | R | 10.6 | R | 11.4 | A | 10.3 | R | 10.2 | H | 11.3 | D | 11.0 |
| 6 | N | 11.9 | O | 11.6 | D | 10.9 | D | 11.8 | T | 11.6 | W | 11.3 |
| 7 | D | 12.2 | H | 12.2 | N | 11.2 | N | 11.9 | P | 11.8 | O | 11.7 |
| 8 | C | 12.3 | N | 12.4 | J | 11.5 | O | 12.1 | N | 11.9 | G | 12.2 |
| 9 | O | 12.4 | C | 12.5 | C | 12.0 | C | 12.2 | R | 12.0 | C | 12.2 |
| 10 | H | 12.7 | T | 12.5 | P | 12.6 | L | 12.9 | E | 12.2 | R | 12.3 |
| 11 | E | 12.8 | E | 12.8 | E | 12.8 | E | 13.0 | C | 12.7 | P | 12.4 |
| 12 | L | 12.9 | L | 12.9 | L | 13.0 | H | 13.2 | L | 13.0 | H | 12.9 |
| 13 | T | 13.1 | D | 13.1 | H | 13.5 | J | 13.3 | O | 13.3 | E | 13.1 |
| 14 | P | 13.4 | P | 13.9 | O | 13.6 | T | 13.6 | D | 13.4 | N | 13.3 |
| 15 | K | 14.0 | K | 14.1 | K | 13.8 | K | 13.7 | V | 13.7 | J | 13.6 |
| 16 | J | 14.0 | W | 14.2 | T | 14.0 | P | 13.9 | W | 13.8 | T | 14.0 |
| 17 | W | 14.6 | G | 14.7 | W | 15.1 | W | 14.8 | K | 15.1 | K | 14.2 |
| 18 | G | 14.9 | V | 15.4 | G | 15.3 | G | 14.8 | F | 15.2 | Q | 14.7 |
| 19 | V | 15.8 | U | 15.5 | F | 16.3 | U | 15.8 | G | 15.3 | F | 14.8 |
| 20 | U | 15.9 | I | 15.7 | V | 16.3 | I | 16.1 | X | 16.0 | L | 15.3 |
| 21 | I | 16.2 | X | 15.7 | U | 16.6 | V | 16.4 | U | 16.2 | U | 15.9 |
| 22 | F | 16.2 | J | 15.7 | I | 17.0 | F | 16.6 | J | 17.4 | X | 16.7 |
| 23 | X | 17.1 | F | 16.2 | Q | 17.2 | Q | 17.0 | I | 17.5 | I | 17.6 |
| 24 | Z | 17.3 | Z | 17.0 | Z | 17.6 | Z | 17.1 | Z | 18.0 | V | 18.3 |
| 25 | Q | 17.3 | Y | 17.3 | X | 19.1 | X | 17.4 | Q | 18.4 | Z | 19.2 |
| 26 | Y | 18.3 | Q | 17.4 | Y | 19.7 | Y | 18.2 | Y | 18.5 | Y | 19.8 |
| N*** | 100 | | 60 | | 40 | | 76 | | 24 | | 22 | |
| Rr** | .94 | | .88 | | .91 | | .91 | | .78 | | .78 | |

* = letter
** = reliability coefficient
*** = number of subjects

Horton-1960

"Coefficients of concordance among judges (not shown above) are low, but rankings for the total sample and the age and sex subsamples appear to be quite reliable." (p. 253) In this light, it seemed "justified . . . to pool all the subgroups for an overall ranking, since differences between groups can be attributed to chance differences between different groups of judges." (p. 253)

* * *

3377 Howell-1959

Howell, William C. and Kraft, Conrad L.

Aviation Psychology Lab., Ohio State U. Research Foundation, Columbus

SIZE, BLUR, AND CONTRAST AS VARIABLES AFFECTING THE LEGIBILITY OF ALPHANUMERIC SYMBOLS ON RADAR-TYPE DISPLAYS

Sep 59, 38 p., 17 refs.

Contract AF 33(616)3612

WADC TR 59-536; AD-232 889

Problem: Determine the effect of size, blur, and contrast, and their interactions on the legibility of alpha-numeric characters presented on a radar-type display (light characters on a dark field).

Procedure: Twelve male university students each tachistoscopically viewed individual characters of a randomly arranged, 36-character, alphanumeric, MACKWORTH (modified) set that was back-projected onto a ground glass screen. There were four conditions each of size, blur, and contrast, for a total of 64 conditions. Performance indices were speed and accuracy.

Result: Optimum legibility was obtained at a 26.80-minute visual angle, low blur, and high contrast. Each of the variables and two of the interactions (size vs. blur vs. contrast and size vs. contrast) between them significantly influenced legibility. Implications of the data, and how the procedure and result of this experiment are related to the work of others, were discussed. Specifically, "(t)he major implications of these findings for operational use are these: (a) in a situation employing white-on-black alpha-numeric symbols, maximum legibility may be attained when no blur exists, when contrast is at or above 37 (percent), and when size is approximately 27 (minutes) of visual angle of letter height, and (b) when restrictions prohibit the attainment of this optimum for specific dimensions, legibility can be maintained by suitable adjustment of the other dimensions. These restrictions can also be compensated for in another manner, that of choosing from the confusion data alphabets that minimize the effect of the restriction." (p. 19) An appendix reports on confusion data derived from specific conditions.

* * *

2160 Howell-1961

Howell, William C. and Kraft, Conrad L.
Ohio State U., Columbus

THE JUDGMENT OF SIZE, CONTRAST, AND SHARPNESS OF LETTER FORMS

Journal of Experimental Psychology, 61:1 (January 1961) 30-39

Problem: Psychophysically quantify the "three variables involved in figure recognition: image size, blur, and contrast." (p. 30) In addition, "examine the efficiency of . . . techniques for scaling directly perceived magnitudes . . . More specifically, . . .: (a) Is (a subject) able to judge and assign numerals to magnitude in a consistent fashion for relatively complex dimensions such as size and blur? (b) Is (a subject) able to abstract these dimensions from complex, meaningful stimuli such as letters of the alphabet? (c) Do the functions obtained for these dimensions correspond to the functions obtained by others for basic dimensions involving less complex stimuli?" (p. 30-31)

Procedure: "Three experimental investigations were undertaken . . . . In each, the . . . magnitude estimation described by Stevens was used . . . . The first study was concerned with the scaling of apparent size, sharpness, and contrast individually under optimal conditions of the other two dimensions. The second and third studies were aimed at determining the extent to which judgments along the individual continua are independent of the level of the other two stimulus dimensions." (p. 31) The apparatus used was designed by Fry and Enoch of the Mapping and Charting Research Laboratory of the Ohio State University. Stimuli were projected from the rear of the apparatus onto a ground glass screen. Variables were manipulated within the apparatus. "The (subject) viewed the stimulus through a 2-(millimeter) artificial pupil, the image appearing in the center of a limitless, uniformly illuminated (3.5 foot-candles) field. . . The size, blur, and contrast levels of the stimuli . . . were specified as follows: (a) size, in minutes of visual angle of letter height . . .; (b) blur, in units based on the ratio of light-dark transition width to stroke width; and (c) contrast, in the ratio of figure-minus-background to background illuminance." (p. 32) For scaling procedures, the standard was designated by the number 10, and differences from this were to be judged by the subject in a linear fashion. In Experiment 1, 16 college student subjects viewed the alphabetic letters I, O, H, and F, under the conditions previously stated. The "physical specification(s) of the stimulus levels used for each dimension in ." . . (p. 33) this and the following experiment were as follows:

| size (min. of visual angle) | blur distribution / stroke width | contrast $\frac{B_1 - B_2}{B_2}$ |
|---|---|---|
| 4.73 | 0.00 | 1.43 |
| 8.20 | 0.55 | 4.14 |
| 11.25 | 1.04 | 8.14 |
| 15.00 | 1.54 | 12.14 |
| 18.25 | 2.09 | 16.14 |
| 21.60 | 2.58 | 20.71 |
| 24.60 | 3.13 | 25.29 |
| 27.00 | 3.63 | 29.39 |
| 31.00 | 4.18 | 33.29 |
| 36.79 | 4.67 | 37.57 |

(above from p. 33)

In the second experiment, 5 student subjects viewed stimuli at "one level of standard-variable figure heterogeneity (.50) . . . ." (p. 35) In order to determine whether "judgments along one dimension (are) independent of the values of the other two. . . each dimension . . . was scaled with the other two at 75 (percent) recognition threshold values." . . (p. 35) of 4.73 minutes for size, 1.43 percent for contrast, and 4.67 blur units for sharpness. In Experiment 3, 4 of the 5 subjects from Experiment 2 viewed "(a) rectangular figure resembling the letter 'I' . . . . Its width was varied systematically . . . between .25 . . . and 16.00 (minutes) visual angle, and its height remained constant at 36 (minutes). . . (This) study was designed to determine the influence of varying two dimensions (sharpness and contrast) individually on judgment of a third (size). . . (Ten) size steps were judged under . . .: (a) . . . high sharpness, high contrast, (b) . . . low sharpness, high contrast, and (c) . . . high sharpness, low contrast." (p. 36)

Result: "In all three experiments . . . the method of magnitude estimation yielded systematic and reliable scales for each of the variables investigated. Only the judgments of sharpness under minimal size and contrast . . . appear to include serious amounts of variability . . . (p. 37) The results indicated that size and sharpness judgments are linearly related to their physical counterparts (letter height and blurredness), whereas the function for contrast is most adequately described by a hyperbolic equation. Reducing two of the three dimensions to legibility threshold does not appear to exert a serious influence upon judgments of size and contrast, although it does effectively disrupt sharpness judgments. Whether a change in the sharpness function also results from the reduction in size and contrast is difficult to ascertain . . . . Reduction to recognition threshold of contrast and sharpness taken individually has a small, but statistically reliable, effect on size judgments, such that reduced sharpness increases the apparent size of the stimulus figure and reduced contrast decreases it." (p. 39)

* * *

2198 Huey-1916

Huey, Edmund Burke

THE PSYCHOLOGY AND PEDAGOGY OF READING

New York, Macmillan Co., 1916, 469 p.

Problem: With a view to the history of writing, reading, and reading methods, discuss the application of empirical investigations performed by the author and others to the problems of the psychology, pedagogy, and hygiene of reading.

Procedure: The following outline of contents gives clues to the scope and coverage of the book:



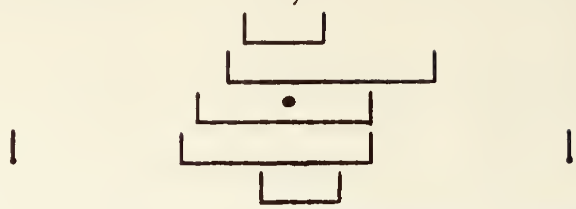
Result: The following excerpts concern the legibility and readability of alphabetic and syllabic characters and symbols (excluding pictographs) and are especially appropriate to the subject matter of this Reference Handbook. Also, these excerpts are representative of the types of material found elsewhere in the text. This book, however, does not attempt to

analyze "what we do when we read . . . (for that) would be to describe very many of the most intricate workings of the human mind (and the processes of perception), as well as to unravel the tangled story of the most remarkable specific performance that civilization has learned in all its history." (p. 6)

1. In reading, the eyes move "by a succession of quick, short movements to the end (of the line), then return in one quick, usually unbroken movement to the (beginning of the next line at the) left. . . (T)here are at least two pauses for every line, and almost always more than that for lines of this (3-1/2 inches) length, ---from three to five . . . usually, and even more when the reading proceeds very slowly. . . (S)ome of the pauses are very much longer than others. . . Javal . . . concluded that there was a pause about every ten letters, and . . . that this was about the amount that could be seen clearly at one fixation." (p. 16-18)
2. "Javal . . . found that after reading he had after-images of straight gray lines corresponding to the parallel lines of print . . . ." (p. 18)
3. "Javal . . . concluded that the fixation point moves along between the middle and top of the small letters. . . (T)he conclusion was shown to be unfounded." (p. 18 & 31)
4. "Javal . . . stated that the movement was such as to prevent the seeing of what was read except during the reading pauses." (p. 18)
5. "Landolt . . . concluded that on an average 1.55 words were read per reading pause, at the ordinary reading distance. Reading of a foreign language required more pauses, as did also the reading of detached words, numbers, and lists of proper names. He found that the small movements were very fatiguing, and that, since the angular excursion increases as the reading matter is brought nearer to the eye, this may account for the tendency of children . . . to myopia. Doubling the distance of the page from the eye increased the number of movements in the ratio of nine to seven, the number of eye-movements seeming to depend upon the visual angle subtended." (p. 19)
6. "(M)ore movements are made by . . . slow readers." (p. 20)
7. "Erdmann and Dodge . . . found that the number of pauses did not vary greatly from line to line, for the same reader and with easy familiar reading matter. There were fewer pauses with familiar matter." (p. 20)
8. "In reading from a . . . treatise, printed in English, with lines 83 millimeters in length, Dodge . . . averaged from three to five pauses per line, according to the familiarity . . . . Erdmann . . . averaged from five to seven pauses . . . in reading a familiar German scientific work, with lines 122 millimeters in length." (p. 20)

9. "Proof reading required about three times as many pauses . . . in the case of Erdmann." (p. 21)
10. "In writing there seemed to be a pause for about every two letters . . . ." (p. 21)
11. In reading, "the first pause was almost always within the line, and . . . the last was still farther from the end of the line. The more familiar the text, the greater was the indentation at the left, and more especially still at the right." (p. 21)
12. "(F)ixations . . . in reading were almost exclusively upon words, upon the middle of the word usually." (p. 21)
13. "Dodge . . . showed that the forward movements varied from two to seven degrees . . . ." (p. 22)
14. "It seems to me (Huey) probable that the fixation point varies more widely than (between the middle and top of the small letters), but there is nothing to indicate that it wanders perceptibly above or below the line." (p. 27)
15. "The return sweep when a line was finished was usually without interruption, although about once in six lines a halt would be made near the end of the movement . . . . These halts . . . are more numerous in reading long lines." (p. 27)
16. "In reading lines of the length (3-3/4 inches) . . . movements . . . (u)sually . . . were from four to six. . . Doubling the distance did not appreciably lessen the number of pauses per line." (p. 29)
17. "(L)ines of the length (2-3/8 inches) and type (about 8-point) shown . . . gave an average of 3.6 pauses . . . (L)ines (2 inches) and type (about 6-point) . . . gave 3.8 pauses . . . for one reader and 3.4 for another." (p. 30)
18. "From 78 per cent to 82 per cent of the line, on an average, was actually traversed by the eye . . . ." (p. 30)
19. Tests in which the subjects "were asked to read as fast as possible", as opposed to reading at their own rate, there was a decrease in both the number and duration of fixations. There was also an increase in the extent, but <u>not the speed</u> of the eye-movement. The results of the author's experiments "are fairly congruent with those of Erdmann and Dodge . . ., except as to the rate of movement. . . The essential problem as to the movements in reading is to know whether they are of such a speed as to prevent our perceiving letters or words during the movement." (p. 33 & 35)
20. "Cattell advanced the hypothesis that the visual organs respond to retinal changes more rapidly when the eye moves than when the objects are in motion . . ." (p. 36)
21. When fixating on a central point, "Erdmann and Dodge, . . . on a page of German printed in good type, found that neither of them could see letters or words clearly beyond the ends of the lines represented in the diagram below . . . . Not all of

even this amount could be seen clearly.



" (p. 52)

22. "It was found by . . . various . . . experimenters, that when printed matter was exposed . . . for . . . about one one-hundredth of a second, more could be read, or the same amount could be read more easily, than when the exposure was longer." (p. 54)

23. "Erdmann and Dodge found that a German reader, in a single exposure lasting one-tenth of a second, read correctly sentences consisting of from four to six words of two to ten letters each, and occasionally recognized a simple word even at the end of a sentence of seven words, containing twenty-six letters. The middle of the sentence was fixated in all cases." (p. 61) Messmer found similar results, "(b)ut like the writer, he found certain readers with a curiously limited reading range. . . Cattell('s) . . . readers . . . were usually limited to four words." (p. 61-62)

24. "Erdmann and Dodge found that words could be read at a distance from the reader which made the constituent letters unrecognizable when presented singly. . . (and) that even very familiar short sentences were sometimes recognized as wholes under conditions which prevented recognition of their constituent words." (p. 62-63)

25. "Erdmann and Dodge found that while but four or five nonsense letters could regularly be read at a single (short) exposure, words consisting in the aggregate of four or five times as many letters were read under similar conditions. . . They believe, however, that for the words, as for the nonsense letters, only an extent of six to seven letters is clearly perceived . . . It was found, too, that . . . nonsense words gave readings that were three or four times as large as readings from nonsense letters . . . ." (p. 64)

26. Zeitler found the following order of difficulty in reading (hard to easy):

    "consonants in nonsense arrangement, such as v c p f n g l w. . . four to seven at an exposure"

    "consonants in nonsense arrangement, . . . with vowels interspersed from five to eight could be read"

    "(a) series of familiar syllables joined continuously, as lencurbilber, losverkungwei . . . six to ten letters being read"

    "series of unfamiliar words"

    "series of . . . familiar words"

    "sentences"

"familiar expressions or proverbs"

"sentences of four or five short words, with a total of twenty to thirty letters"

"(s)ingle words having as many as nineteen to twenty-five letters each, as <u>Bewusstseinszustand</u> and <u>Aufmerksamkeitsschwankung</u>" (p. 64-65)

27. There is a suggestion that as one receeds farther from the fixation point, the items to disappear are first "the small marks" (p. 67) (serifs?), then the dots, then the small letters, then the large letters, and finally the word outlines.

28. "Two facts . . . are evident . . .: First, reading . . . go(es) on by other means than the recognition of letters; second, the amount . . . read . . . will vary with the nature of the matter read, with the associative connections existing between the letters, words, etc., and with the reader's familiarity . . ., the latter enabling . . . clear(ing) (of) . . . parts that are indistinct. . . (W)e are limited, in the amount that can be read during a reading pause, by the inadequacy of the retinal structure, by our inability to attend to more than a few parts of the total picture presented, and by the necessity of our attention's concerning itself with interpretations." (p. 68 & 70)

29. "Cattell . . . concluded . . . that we read in word-wholes and even, sometimes, in phrase or sentence wholes, and not by letters. . . that the shortest exposure which would permit the recognition of single small letters and capitals sufficed also for the recognition of short words, and that long words needed but one one-thousandth of a second more." (p. 72-73)

30. Erdmann and Dodge found: "First, words are recognized when lying too far from the fixation point to permit recognition of their component letters. Second, words are recognized when formed of letters so small that the letters could not be singly identified. Third, . . . words were recognized at distances at which the letters when exposed singly, could not be recognized. Fourth, . . . words were more readily recognized when they were long, or of optically characteristic form. Fifth, when twenty-six selected words were learned thoroughly in a fixed order, as the alphabet is known, and then exposed beyond the distance at which the letters could be recognized, the words could be distinguished and recognized in almost every instance. Sixth, words of four letters are named somewhat more quickly than single letters, and words of eight, twelve, and sixteen letters need comparatively little more time, the longest needing only about one-fifth more time than the shortest." Thus, "it is not the constituent parts of any given form that make it recognizable, but it is the familiar total arrangement. . . ¯ ′ ɔ is not

recognized as 5 nor ⟨I as K . . . The arrangement g has all the elements of a

n

i

d

a

e

r

familiar word and, indeed, in their usual order. But it is by no means the visual form recognized . . . in the word reading." (p. 73-74)

31. "Goldscheider and Müller . . ., working earlier than Erdmann and Dodge, found" similar results with the grouping of strokes, squares, semicircles, ellipses, mixed symbols, parts of numbers, and nonsense letters, syllables, words, phrases, etc." (p. 75)

32. Münsterberg concluded "that 'reproduced sensations under favorable conditions cannot be distinguished from sense impressions.'" Goldschieder and Müeller used the following German examples to substantiate his thesis:

    "C ntr m . . . sufficed for recognition of . . . Centrum, but ent um did not"

    "Klangbild . . . from Kl ngb ld, but not from lan bild"

    "M k do gave Mikado, but Mik o . . . gave only Mikosch"

    "Ch tė gave Charitė at once" (p. 79-80)

33. "To the determining letter class belongs the first letter of a word, almost always." For example:

    "Autor was never recognized from utor"

    " eweis did not give Beweis . . ., but edelweiss"

    " weifel did not give Zweifel, but Weibel"

    " ia n se was completed to Wannsee, and . . . Diagnose could not be made out" (p. 80)

34. "Goldscheider and Müller do not find that the consonants are the determining letters as against the vowels as indifferent letters . . . . For instance, Diagnose was recognized with greater difficulty when D gn se was presented than from D a nose. The . . . importance of the vowels . . . may be . . . the clew to the number of syllables, . . . the rhythm and the accent. Or . . . the vowel sound is of 'determining significance' . . . (C)onsonants, however, from their frequent projecting above or below the line, are apt to contribute more than the vowels to the characteristic form of the word." (p. 80-81)

35. "In general, (Goldscheider and Müller) conclude that . . . (w)ith increase in familiarity, . . . reading is now by letters, now by groups of letters or by

syllables, now by word-wholes, all in the same sentence sometimes, or even in the same word, as the reader may most quickly attain his purpose." (p. 81)

36. Zeitler, in studying determining or "dominating" parts, found that "letters projecting above or below the line were recognized preferably. The vowels and small consonants were misread most often, the long consonants least often. . . (E)xamples of the dominating letters may be . . . the following:

| | |
|---|---|
| Gold | G ld |
| Haut | H t |
| Fliege | F lg (sic) |
| Woche | W ch (ck) (sic) |
| Streit | St t |
| Minute | M t " ( p. 82-84) |

37. "The dominating parts may be silent letters, or letters having a sound that is very different when heard singly than when combined in the given word." (p. 85)

38. "The reading stimulus . . . is ordinarily not the . . . sentence or the . . . words . . . (b)ut . . . is the series of dominating letters or complexes." (p. 85)

39. "In Zeitler's opinion, . . . word-length and total form are not very important factors in the recognition." This result came from the following words being read for the exposures given:

| exposure | reading |
|---|---|
| Phalanstère | Phantasie |
| | Polarstern |
| Skioplikon | Skorpion |
| | Skioptikon |
| Pygmalion | Pygmae |
| Lepidodendron | Leoparden |
| Ritardando | Retoranda |
| Epaminondas | Epimenides |
| Agoraphobie | Agraphie |
| Farbe | Fabrik |
| Meludie (exposed for Melodie) | Medulla |
| Gefüdl (Gefühl) | Gefilde |
| Külge (Külpe) | Klage |
| Fniede (Friede) | Feinde |
| Analomie (Anatomie) | Anomalie |

Thus also, "in the first perception . . . the dominant parts . . . are not seen in

any very fixed spatial arrangement, but are later put in place . . . when the full recognition completes itself with . . . the associative elements." (p. 85-87)

40. "Messmer finds that the long letters which project above the line are usually the dominating ones. . . Letters projecting below the line would be mistaken for vowels, as g for a, p for o, etc. 'They possess optically the value of small letters.'" (p. 91)

41. "The dominating letters play the main role in recognition, but the others . . . play an important part as well." (p. 91)

42. "Readers of (one) type apperceive . . . from the total character of the word-form rather than from the dominating parts . . ." (p. 92) and, at a glance, read a larger amount, less accurately, than do the ones who utilize the dominant letters.

43. "Small letters adjoining the dominant letter may, by their proximity, help in forming a total configuration and . . . thus . . . a dominant complex." (p. 92)

44. Messmer "finds that word-length plays little part in characterizing words for children, and that it is usually less important for children than are the dominant complexes." (p. 93)

45. "Messmer's analysis of the 'total character of words' has . . . three main factors . . ., first, breadth of the letters horizontally; second, height of the letters vertically; third, geometrical form of the letters. As to breadth, the letters are composed of one, two, or three vertical strokes, as i, h, m, or of forms occupying one or another of these three horizontal spaces. . . Differentiation in letter-width (73.0 percent of German text letters are small) . . . seems to be of comparatively little value. . . Viewing the total word-form as to height, (the) long letters vary it and give a characteristic outline." (p. 93-94) Compare Zusammenreisen with Verschiedenheiten. "(L)etters may be grouped, first, into those composed essentially of vertical strokes, as i, n, m, t, l, f, h, r, j; second, those composed essentially of curved lines, as o, e, c, s, a, g; third, those composed essentially of both perpendicular strokes and curved lines, as b, d, q, p; fourth, those composed essentially of oblique strokes, as, w, v, y, x, z, k, the last letter having also a perpendicular stroke." In frequency (German text), the following breakdown is seen:

| | | |
|---|---|---|
| group one | (i n m t l f h r j) | = 46.9% |
| group two | (o e c s a g) | = 37.1% |
| group three | (b d q p) | = 6.1% |
| group four | (w v y x z k) | = 4.6% |
| (capitals---more frequent than in English) | | = 6.3% |
| total = 101.0% (sic) | | |

"The predominance of one or another of these classes of letters, in any given word, gives it a characteristic total appearance . . . Messmer calls . . . the total impression . . . in . . . words . . . containing about equal numbers of . . . the first two groups . . . 'the most favorable total form' . . . ." (p. 94-95)

46. "Messmer . . . thinks that for (child readers) . . . word-length is but a minor factor in word-perception." (p. 96)

47. "In experiments made some years ago I found that the first half of a word is of considerably greater importance for perception than is the latter half. . . (T)he beginning of a word was regularly found to be a determining or dominating part . . . . Indeed, the terminal letters are considerably more legible than the others, perhaps from being partially isolated. . . (R)eaders tested averaged .49 words per second when reading from the first halves, as against .33 words per second when reading from the last halves. . . (F)actors which coöperate to produce this result (are) . . . the tendency of English to place the accent upon the first part of the word, . . . the preponderance of . . . suffixes over prefixes, . . . (and) the time-order (from the first part toward the latter) in ordinary inter-association of syllables . . . ." (p. 96-98)

48. "The upper half of a word or letter is . . . more important for perception than is the lower half. . . Javal . . . concluded . . . that the eye's fixation point moved along between the middle and top of the small letters, thus giving an advantage in perception to the upper half of the line. . . (I)t seems to me that the greater importance of the upper part is due rather to the words being better differentiated there than below, as . . . shown by Messme(r) . . . ." (p. 98-99)

49. "In my own experiments . . . it seems certain that the recognition of familiar and comparatively short words is little affected by doubling the number of letters . . . ." (p. 101)

50. "(O)ne is inclined to accept what the experiments of Zeitler, Messmer, and others seem to show, that the first factors of perception in reading are not usually the total form, word-length, etc., but certain striking 'dominant' parts, . . . word-form and word-length coming a little later as the recognition is completed at the suggestion of these dominant cues." (p. 109)

51. "There is no question but that . . . recognition could well be set off by a skeleton drawing of the word showing no particular letter forms, and might well occur at distances at which particular letters were no longer recognizable as such. . . But Erdmann and Dodge have . . . apparently mistaken what is possible and many times actual for a usual and almost universal method of recognition. Here the testimony of the majority of . . . experimenters is against them. . . As a matter

of fact, the outline form of a word is a rather inconstant quantity." (p. 110)

52. "When a single letter is exposed and recognized . . ., the simultaneously given stimulations from its various parts mutually reënforce each other, having been associatively knitted together in past experience. . . Doubtless we have dominant parts of letters as of words." (p. 112)

* * *

2667 Hughes-1961

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VARIABILITY OF STROKE WIDTH WITHIN DIGITS

Journal of Applied Psychology, 45:6

(December 1961) 364-368, refs.

Problem: After a review of the literature and conclusions drawn from it concerning digit design, "(t)he present study was an attempt to study systematically the effect of variations in within-variable stroke width, CONVENTIONAL versus SYMBOLIC digits, emphasizing the unique aspects of digits through stroke boldness, angularity versus curvature, and the interaction of these variables." (p. 365)

Procedure: Subjects viewed stimuli (illuminated at 100 foot-candles) from 21 feet. "(T)his was decreased by one-foot intervals until (the subject) could read the digit correctly. . . (p. 366) The stimuli were a set of cards on which the digits were drawn, one digit per card, each digit 9/64 (inches) high . . . . The stroke width to height ratios . . . were either 1 (to) 6 (emphasized) or 1 (to) 8 (unemphasized). . . Eight 'types' of digits, (1 through 0) of each . . . were used . . . . Some . . . were duplicate(d) . . . to prevent i(m)balance in . . . presentation . . . and as an offset for guessing habits . . . . The types were:

"Type A---conventional ARABIC, even-overall stroke width, (stroke width to height ratio) 1 (to) 8

"Type B---conventional ARABIC, even-overall stroke width, (stroke width to height ratio) 1 (to) 6

"Type C---SYMBOLIC, even-overall stroke width, (stroke width to height ratio) 1 (to) 8

"Type D---SYMBOLIC, even-overall stroke width, (stroke width to height ratio) 1 (to) 6

"Type E---SYMBOLIC, emphasized horizontal components, (stroke width to height ratios) 1 (to) 6 and 1 (to) 8

"Type F---SYMBOLIC, emphasized vertical components, (stroke width to height ratios) 1 (to) 6 and 1 (to) 8

"Type G---SYMBOLIC, emphasized unique components, (stroke width to height ratios) 1 (to) 6 and 1 (to) 8

"Type H---SYMBOLIC, special design with only unique components, the common elements absent, (stroke width to height ratio) 1 (to) 6

"(T)he following terms ."'. . were defined in the report:

"Form---the shape or contour of the digit irrespective of the stroke variations . . .

"Stroke Width---the ratios of (stroke width) or line emphasis . . .

"Configuration---the total or whole digit including form and (stroke width) variations . . .

"Component---any part or stroke or contour of a digit . . .

"Uniqueness---the condition of having components or element combinations that are not present in other configurations, either through changes in (stroke width) or form . . ." (p. 365-366)

Result: "The primary conclusions which may be drawn from the previous research . . . would appear to be as follows:

1. "The degrees of boldness of stroke lie within the range (stroke width to height ratios) 1 (to) 6 to 1 (to) 8 for best visibility.
2. "Overall width to height ratios may range from 1 (to) 1 to 7 (to) 10.
3. "Angularity increases visibility.
4. "Increased enclosed white space aids visibility.
5. "No adequate theory or hypothesis has yet been formulated to account for the differences in visibility demonstrated in research studies. . . (p. 365)

"The results (of this study) indicated that the symbolic numerals were significantly more visible than the conventional digits, contrary to prior reports. Form and stroke width showed a significant interaction, supporting the conclusion that stroke width could vary within a set of digits or even within a single digit so as to increase the discriminability. . . We can generalize to say that each digit must be designed on an individual configuration basis taking form, stroke widths, and their combinations into account. Two factors must be considered: (a) absolute recognition of the digit as such, (b) differentiation (by relative emphasis) of features that suggest similarity (hence ambiguity) of one digit (to) each of the others. . . Questions still unanswered are: what are the effects of decreasing illumination to near thresholds, tachistoscopic presentation, and the relative perceptability (sic) of groups of the symbolic digits?" (p. 368)

* * *

2580 Hulbert-1957

Hulbert, S. F. and Burg, A.
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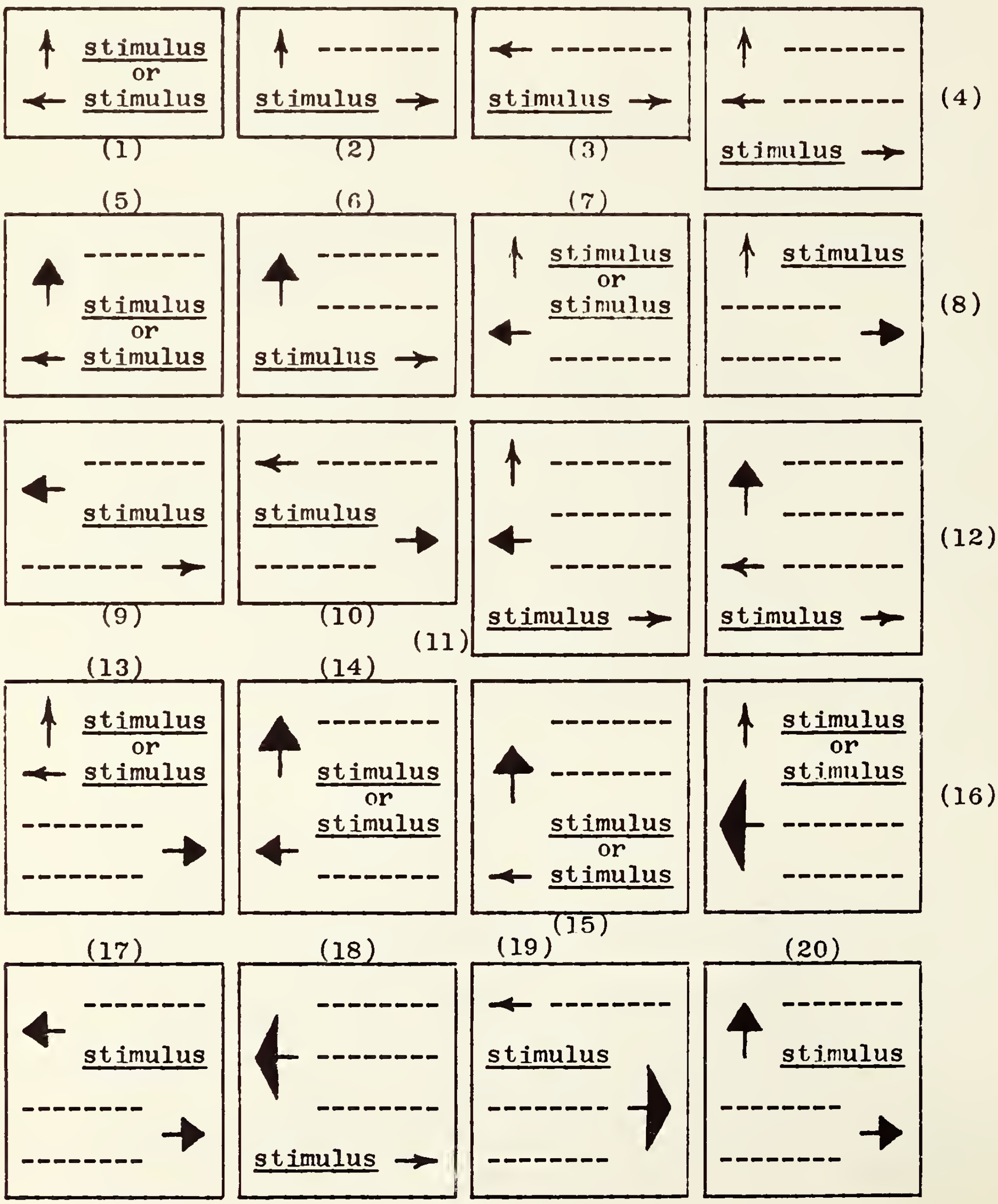
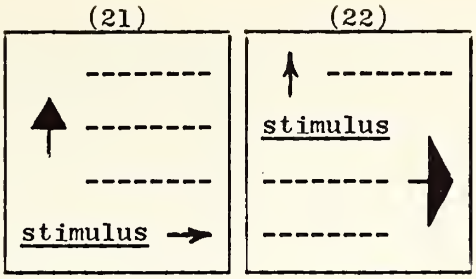
U. of Calif., Los Angeles
THE EFFECTS OF UNDERLINING ON THE READABILITY OF
HIGHWAY DESTINATION SIGNS
In HIGHWAY RESEARCH BOARD, PROCEEDINGS OF THE
THIRTY-SIXTH ANNUAL MEETING, 1957, Herbert P. Orland,
Editor, (Washington, D.C., National Academy of

Sciences-National Research Council Publication 542, 1957), Vol. 36, p. 561-574, 6 refs.

Problem: Considering the readability of the sign as a whole, determine the effect of short and long, thick and thin, and no horizontal dividing lines (separating the different directions only, not necessarily all the place names) on the legibility of geographic names and directional ARROWS on highway destination signs. Ascertain also the interaction among the above and the following: (1) the number of names on the sign, (2) the relative and absolute length of these names, (3) the number of arrows on the sign, (4) the arrow configuration, and (5) the position on the sign of the stimulus name.

Procedure: The possible sign configurations used were as follows:






"Four conditions were investigated:

1. 26-1/2 (by) 1-1/4 (inch) line, centered on the sign (short thick);
2. 42 (full sign width, by) 1-1/4 (inch) line (long thick);
3. 42 (by) 3/4 (inch) line (long thin); and" (p. 561)
4. a "no-line" condition.

"A number of other characteristics . . ." (p. 561) investigated included the following: (1) the number of destinations per sign was 2, 3, or 4, (2) arrow/name configurations as shown above, (3) absolute length of place names was short (5 or fewer letters), medium (6 to 9 letters), and long (10 or more letters), (4) relative length of place names per sign either equivalent or different, and (5) stimulus name at various locations (among the possible four). All the above gave an experimental matrix design of 176 different signs. Each subject saw only 22 of these (with which were mixed 3 "placebo" signs) in the rear projection, motion picture display (photographed from an automobile moving at 33 miles per hour). "The subject was seated (in a light-tight projection room) approximately 2-1/2 (feet) behind a curved (2- by 3-foot) translucent screen." (p. 564) The 140 subjects involved were licensed drivers, ranging in age from 17 to 50 years, 60 percent male, had driving experience of from a few weeks to over 25 years, and visual acuity ranging from 20/40 to better than 20/20. The subject's task was to mark, by drawing an arrow up, right, or left, the direction in which lay the locality that had been verbally called out and visually shown to him as the sign approached. Arbitrary test criteria dictated that there must be no fewer than 4, nor more than 18 errors out of the 22 responses, and that response to the three placebos indicate a guess only rather than a positive answer. Constant in the experimentation were the following: (1) all signs were on posts at the roadside, and (2) the size, style (GOTHIC capitals), and spacing of the letters were "from the manufacturer's stencils," (p. 564) and hence "identical with actual highway signs." (p. 564)

Result: Analysis was by (1) subjects, i.e. who met what criteria, and (2) errors. From the results the following conclusions were drawn:

1. "Underlining (i.e. separating words on the basis of destination direction) reduce(d) the probability of a destination being associated with the wrong arrow in the unequal-word-length signs.
2. "The probability of a sign being misread (was) greater when the place names (were) of equal length than when . . . unequal.
3. "Proportionally more errors were made on the 4- . . . than on the 2- and 3-destination signs.
4. "Proportionally more errors were made on 3- . . . than on 2-arrow signs.
5. "No significant difference among the three styles of underlining was apparent.
6. "No correlation was found between visual acuity and number of misread signs." (p. 570-571)

* * *

3375 InsTUFTS-1952
Institute for Applied Experimental Psychology,
Tufts Coll., Medford, Mass.
LEGIBILITY OF PRINTED MATERIAL
Section II, Chapter IV, Part III of HANDBOOK OF
HUMAN ENGINEERING DATA
Special Devices Center, Human Engineering Technical rept.
SDC 199-1-2a, 1 Nov 52, (9p., 57 refs. of 610p.)
Contract N6-ori-199-T. O. 1
NavExos P-643; AD-43 650

Definition of legibility - "(W)e refer to the fact that printed material varies in the ease with which it can be read." (p. 1)

Measures of legibility - "Some studies evaluate . . . material by the speed with which it can be read. . . Another measure . . . is the maximum distance . . . . This measure is sometimes called . . . perceptibility, and . . . is ordinarily used for small units of material . . . . A third technique is to present the material . . . in a tachistoscope and determine the mimimum time . . . for correct recognition. Visibility is the rating in terms of the units on the Luckiesh-Moss Visibility Meter . . . . A somewhat similar method . . . is the focus method. . . (, a)n image . . . being . . . projected through reciprocal lenses in such a way that it can be varied in clearness . . . without changing the size. Relative legibility can be determined (from this) . . . ." (p. 1)

Physiological and psychological response - "(T)he two most common are the blink rate and the number and kind of eye movements made during the reading process. . . (B)link rate has been (used) in studies concerned with . . . illumination . . . Smooth eye movements with relatively few fixations and regressions . . . have been used as criteria in determining differences in legibility. One other technique is occasionally used. The subject is asked to rate samples of different types of patterns of printing as to . . . pleasingness . . . ." (p. 1)

Factors influencing legibility - "Two . . . groups of characteristics . . . have been considered of importance . . .: a. factors dealing with the characteristics of the printed material itself - the face and size of type, the leading, the length of line, and, b. factors dealing with the characteristics of the background - its color, intensity, brightness relations, and spatial relations. . . Combinations of several conditions, each one of which has only a slight tendency to reduce reading efficiency, will produce significantly slower reading and more eye movements." (p. 1)

Vibration - "Tables, charts, . . . graphs . . .(, and) dials are . . . affected. One set of experiments . . . rotat(ed) prisms between the reading material and the eyes of the reader . . . . (from Crook-1947a and Crook-1947b, both of which appear elsewhere in this volume; and also from Crook et al, STUDIES OF THE EFFECT OF TYPOGRAPHICAL SPACING ON THE LEGIBILITY OF NUMERALS UNDER VIBRATION, U.S.A.F., Air Materiel Command, Wright-Patterson Air Force Base, Aero Medical Laboratory, Engineering Division, MCREXD-694-1Q, 29 November 1949, 18 pp.) In another study the whole book was vibrated in order to achieve the same effect. . . (from Tinker-1948b) (V)ibration, if sufficiently large, reduces efficiency of performance. . . (T)he human body has a considerable tolerance for adverse conditions such as vibration, if the . . . conditions occur singly. When several . . . act together, performance is significantly impaired . . . ." (p. 1-2)

Comparison of type faces - The following rank order was seen in the visibility, perceptibility at a distance, speed of reading and reader opinions of legibility for ten type faces.

| SCOTCH ROMAN versus | visibility | perceptibility | speed of reading | reader opinion |
|---|---|---|---|---|
| ANTIQUE | 1 | 3 | 3 | 2 |
| CHELTENHAM | 2 | 2 | 8 | 1 |
| AMERICAN TYPEWRITER | 3 | 1 | 9 | 6 |
| CLOISTER BLACK | 4 | 10 | 10 | 10 |
| BODONI | 5 | 7 | 4.5 | 3 |
| GARAMONT | 6 | 6 | 1 | 5 |
| OLD STYLE | 7 | 4 | 4.5 | 4 |
| CASLON OLD STYLE | 8 | 5 | 6 | 8 |
| KABEL LIGHT | 9 | 9 | 7 | 9 |
| SCOTCH ROMAN | 10 | 8 | 2 | 7 |

(p. 3) (above table is from Paterson-1940a, which appears elsewhere in this volume; and also from Paterson and Tinker, STYLE OF TYPE FACE, Journal of Applied Psychology, v. 16 (1932) 605-613; and Tinker and Paterson, THE INFLUENCE OF TYPE FACE ON THE LEGIBILITY OF PRINT, Journal of Applied Psychology, v. 19 (1935) 43-52)

Effect of type characteristics on various criteria of legibility - as follows (quoted material is from p. 4):

1. Upper vs. lower case, distance - "Both words and nonsense syllables read at (significantly) greater distance when written in capitals." (from Tinker, THE INFLUENCE OF FORM OF TYPE ON THE PERCEPTION OF WORDS, Journal of Applied Psychology, v. 16 (1932) 167-174)
2. Upper vs. lower case, reading speed - "Lower case reads 13.4 (percent) faster than capitals, and 2.8 (percent) faster than italics." (from Tinker and Paterson, INFLUENCE OF TYPE FORM ON SPEED OF READING, Journal of Applied Psychology, v. 12 (1928) 359-368)
3. Upper vs. lower case and type face, reading speed judgment - "Lower case standard is judged more pleasing and . . . legible than lower case boldface, though reading rates are the same. . .(, and) preferable on both counts to capitals, . . . (but) read 11.8 (percent) more rapidly." (from TinkPat-1942)
4. Type size, eye movement - "Ten-point type induces fewer eye movements than either very large or . . . small type." (from Paterson-1942a)
5. Type size, reading speed - "Ten-point type is read significantly faster than either larger or smaller type." (from Paterson and Tinker, SIZE OF TYPE, Journal of Applied Psychology, v. 13 (1929) 120-129)
6. Width and leading, reading speed - "Extremes . . . lead to slower reading. Optimal reading occurs with 9-point type with 1 to 4 points of leading and with line widths of 14 to 30 picas." (from TinkPat-1949)
7. Line width, reading speed - "Line width of 80 (millimeters) is read significantly faster than either longer or shorter lines; effect is most pronounced for good readers." (from Tinker and Paterson, LENGTH OF LINE, Journal of Applied Psychology, v. 13 (1929) 205-219)
8. Line width, eye movement - "Standard line produces more efficient eye movements than short (or long) line(s), with exception that there were more regressions for standard line . . . ." (from Paterson-1942b)
9. Medley, reading speed - "Speed of reading is significantly reduced . . . and increase in variation in medley slows reading further. Slight amount of medley . . ., however, is judged more pleasing." (from TinkPat-1946b)
10. Grouping of digits, speed of perception - "When no fixation point was used, 6 digits were more accurately reported when presented by means of tachisto(s)cope in 2 groups of 3 extending 7 (centimeters), rather than in 3 groups of 2, especially at short exposure times. . . (M)ore widely-spaced groups of 2 equalled more compact groups of 3 in legibility and were superior to widely-spaced groups of 3, if

exposure was short. At long exposure, 3's were better . . . . When fixation point was used, grouping in 2's was . . . superior." (from Dixon-1948)

11. Letters and digits, speed of perception - from most to least legible: Lower case - k, d, q, ○, b/p, 7/m, w, f, △, 9/□, =, 6, h, j/?, y, σ, 0, r/t, x, ✓, v/3/8, +, 2, 5, z, 4/c, o, a/u, g, ±, %, π/÷, e, i, n, 1 (one), s, l (ell). Upper case - W, Z, X, O, D, M/P, =/Σ/Y/U, △, 9, N, J, ○, ?, 7, Q/K, H, C/S/3, 4/□/L, 2, T, 1, 8, 6, F, B, +, 5, ✓/%/R/G, E, A, 0, ±/I, ÷. (from Tinker, THE RELATIVE LEGIBILITY OF THE LETTERS, THE DIGITS AND OF CERTAIN MATHEMATICAL SIGNS, Journal of General Psychology, v. 1, (1928) 472-495)

Characteristics of background that affect legibility - as follows (quoted material is from p. 5):

1. Black vs. white, reading speed - "Black on (w)hite read . . . (significantly) more efficiently than (w)hite on (b)lack." (from Paterson and Tinker, BLACK TYPE VERSUS WHITE TYPE, Journal of Applied Psychology, v. 15 (1931) 241-247)
2. Black vs. white, distance - "Black on (w)hite . . . (significantly) more legible than (w)hite on (b)lack." (from Holmes, THE RELATIVE LEGIBILITY OF BLACK PRINT AND WHITE PRINT, Journal of Applied Psychology, v. 15 (1931) 248-251)
3. Black vs. white, comparison of apprehension, peripheral legibility, eye movements, and distance - "Regardless of . . . measurement used, (b)lack print on (w)hite background is superior to (w)hite on (b)lack. . . (, and) is more marked for those situations in which there are no pattern or meaning cues to aid in perception, i. e., for isolated letters, nonsense words, etc." (from Taylor, THE RELATIVE LEGIBILITY OF BLACK AND WHITE PRINT, Journal of Educational Psychology, v. 25 (1934) 561-578)
4. Black vs. white, distance - "When digits 80 (millimeters) in height are used, a. Optimal stroke width for (w)hite on (b)lack (equals) 6 (millimeters), for (b)lack on (w)hite (equals) 10 (millimeters), b. When of optimal proportions, single digits of (w)hite on (b)lack can be recognized 8. 8 (percent) better than (b)lack on (w)hite. c. Figure 8 is most legible when lines cross in middle at about 90 (degree) angle. Optimum form recognition was found in each case to depend on sharp angle in crossing lines and equality of parts. d. When 5 digits come together, outer distance between numbers must be increased 10 (percent) to be equally as legible as standard. e. Frame of (w)hite lines same width as those forming digits increases legibility though one either narrower or wider decreases legibility." (sic) (from Berger-1944b, which appears elsewhere in this volume; and also from PART I of the same study, which appeared in Journal of Applied Psychology, v. 28 (1944) 208-231)
5. Achromatic vs. chromatic, eye movements - "42. 6 (percent) retardation (over black on white) in (r)ed on (g)reen situation." (from TinkPat-1944a)
6. Achromatic vs. chromatic, reading speed - "Green on (w)hite, (b)lue on (w)hite, (b)lack on (y)ellow . . . are almost as quickly read as (b)lack on (w)hite; . . . (o)range on (b)lack, (o)range on (w)hite, (r)ed on (g)reen, (b)lack on (p)urple . . . produce very slow reading." (from Tinker and Paterson, VARIATIONS IN COLOR OF PRINT AND BACKGROUND, Journal of Applied Psychology, v. 15 (1931) 471-479)
7. Achromatic vs. chromatic, distance - "Blue on (w)hite is most legible, . . . (g)reen on (w)hite, (b)lack on (w)hite, and (g)reen on (r)ed are approximately equal . . . (, and r)ed on (g)reen (is) least. Very legible combinations . . . (have) marked brightness differences. Close correlation indicated between this . . . and reading speed . . . (from Preston et al, THE EFFECTS OF VARIATIONS IN COLOR OF PRINT AND BACKGROUND ON LEGIBILITY, Journal of General Psychology, v. 6 (1932) 459-461) Hue relatively unimportant. (Brightness c)ontrast . . . is significant variable: (b)lue on (g)ray, (b)lack on (g)ray, (b)lack on (y)ellow, (r)ed on (g)ray most legible, (b)lue on (b)lack, (y)ellow on (w)hite, (b)lack on (b)lue, (r)ed on (b)lack, and (r)ed on (g)reen least legible." (from

Sumner, INFLUENCE OF COLOR ON LEGIBILITY OF COPY, Journal of Applied Psychology, v. 16 (1932) 201-204)

8. Type of surface, reading speed - "Finish and color (sic) of paper have no (statistically significant) effect on speed of reading." (from Stanton and Burtt, THE INFLUENCE OF SURFACE AND TINT OF PAPER ON THE SPEED OF READING, Journal of Applied Psychology, v. 19 (1935) 683-693; with similar results from Paterson and Tinker, PRINTING SURFACE, Journal of Applied Psychology, v. 20 (1936) 128-131)
9. Type of surface, distance - "Paper surface has no effect on distance at which words can be read." (from Webster and Tinker, THE INFLUENCE OF PAPER SURFACE ON THE PERCEPTIBILITY OF PRINT, Journal of Applied Psychology, v. 19 (1935) 145-147)
10. Letter brightness, distance - "When all letters on (a single stimulus object) are same brightness, . . . no differences are completely reliable. When black, dark and light gray letters are mixed . . . black and dark gray letters are recalled significantly better . . . ." (from Taylor and Tinker, THE EFFECT OF LUMINOSITY ON THE APPREHENSION OF ACHROMATIC STIMULI, Journal of General Psychology, v. 6 (1932) 456-458)

Effects of illumination on legibility - "(It) depends on three factors: brightness of light to which subject is adapted; sort of light being used; and criterion used. Subject . . . prefers light . . . to which he is adapted, when . . . indirect, but . . . considerably brighter . . . if direct illumination is being used. Only low illumination (below 7 foot-candles) has detrimental influence on rate of reading, and if subject is allowed . . . to adapt, less than 3 (foot-candles) has no effect. (sic) . . (Use of) blinking or heart rate as indicators of efficiency . . . is . . . open to question . . . ." (p. 6) (the above effects of illumination are from Rose-1946, which appears elsewhere in this volume; and also from Tinker, THE EFFECT OF ILLUMINATION INTENSITIES UPON SPEED OF PERCEPTION AND UPON FATIGUE IN READING, Journal of Educational Psychology, v. 30 (1939) 561-571; Tinker, EFFECT OF VISUAL ADAPTATION UPON INTENSITY OF ILLUMINATION PREFERRED FOR READING WITH DIRECT LIGHTING, Journal of Applied Psychology, v. 29 (1945) 471-476; Tinker, EFFECT OF VISUAL ADAPTATION UPON INTENSITY OF LIGHT PREFERRED FOR READING, American Journal of Psychology, v. 54 (1941) 559-563; and Tinker, ILLUMINATION INTENSITIES FOR READING NEWSPAPER TYPE, Journal of Educational Psychology, v. 34 (1943) 247-250) Proper illumination levels are cited as follows:

| | |
|---|---|
| Critical levels: | |
| 10-point type | - 3 to 4 foot-candles |
| newspaper | - 7 foot-candles |
| With allowance for margin of safety, following are recommended: | |
| good print | - 10 to 15 foot-candles |
| newsprint | - 15 to 20 foot-candles |
| handwriting | - 20 to 30 foot-candles |
| 6-point type | - 30 to 40 foot-candles |
| most severe | - 40 to 50 foot-candles |

(p. 6) (above table is from Tinker, ILLUMINATION STANDARDS FOR EFFECTIVE AND EASY SEEING, Psychological Bulletin, v. 44, (1947) 435-450)

Effect of vibration on visual tasks - as follows:

1. Ability to discriminate digits - "High frequency of vibration is one of factors producing most impairment of performance. Increased amplitude of vibration more more important than particular pattern in reducing efficiency. Reading time and errors both reflect greater difficulty of task when combination of unfavorable factors is compared to favorable combination (e. g., low illumination, high amplitude, small type vs. high illumination, low amplitude, large type)." (p. 7)

(from Crook et al, referred to in paragraph 5 above)

2. Reading speed - In one experiment, there was a "5 (percent) reduction in speed" (p. 7) of reading text material. (from Tinker-1948b)

* * *

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Karmeier, Delbert F., Herrington, C. Gordon and Baerwald, John E.
Illinois U., Urbana
A COMPREHENSIVE ANALYSIS OF MOTOR VEHICLE PLATES
In HIGHWAY RESEARCH BOARD, PROCEEDINGS OF THE THIRTY-NINTH ANNUAL MEETING, 1960, Herbert P. Orland, Editor, (Washington, D.C., National Academy of Sciences-National Research Council Publication 773, 1960), Vol. 39, p. 416-440, 17 refs.

Problem: "This . . . analysis of motor vehicle license plates was conducted with the following objectives ." . . (p. 416) in mind:

1. "(D)etermine the functions (and their relative importance) of license plates . . .
2. "(D)etermine what information (and the relative importance of each item) should be displayed . . .
3. "(D)esign the most (economical, ) effective(, ) and efficient license plate." (p. 416)

Procedure (general): "To determine the functions of a license plate and their relative importance (1., above), 475 questionnaires were distributed to (American and Canadian) persons concerned with vehicle licensing. Analysis of the questionnaire returns provided information whereby the other two objectives of the study (2. and 3., above) could be analyzed. This, together with an extensive literature search, was supplemented by additional field and laboratory tests." (p. 416) More specifically, the study was directed toward the following functional, information, and design considerations: (1) legibility distances for registration and year numbers, and state name, (2) important characteristics of the registration number, (3) importance of color in year identification, (4) value of county or area identification, (5) the value of slogans in state identification, (6) importance of two (front and rear) license plates, (7) plate size and shape, (8) number and letter-number combinations, (9) relative legibility of letters and numbers, (10) size of state name and year numbers, (11) effect of slogans on legibility, (12) color combinations, (13) miscellaneous factors such as registration procedures, area identification, and motor vehicle laws, and (14) reflectorization of license plates. "(D)esign items . . . studied (were) (a) composition and size of the . . . registration number, (b) size of state name and year number, (c) the effect of slogans and emblems, and (d) color combinations. The size and shape (of the plate), which would logically be determined on the basis of . . . design items, have instead been (previously) standardized (at 6 by 12 inches) . . . Miscellaneous factors that affect design are materials and paints, distribution methods, registration procedures, and various motor vehicle laws." (p. 419) Thus, the material herein covers first, the results of the questionnaires, second, the findings of the literature search, and third, the procedures and results of the field and laboratory experiments performed---all, for the most part, in terms of the fourteen items shown above.

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Result (questionnaires): "(L)icense plates are being used to carry many different items of information. . . (r)egistration numbers and letters, county names, county or area code numbers or letters, congressional district numbers, state names, year numbers, state slogans, emblems, and weight indications . . . Sixty-two percent of the questionnaires were completed and returned. . . On the basis of the replies . . ., the following conclusions concerning the functions of license plates were evident:

1. "The primary function . . . is to display the information necessary for fast and accurate identification of a motor vehicle under actual traffic conditions. This . . . is accomplished by . . . the . . . registration number and the state name . . . .
2. "The second function . . . is to display . . . compliance with the . . . registration laws . . . . This . . . is accomplished by . . . year number . . ., by changing the color . . ., and by . . . special designations for differing types and weights of vehicles.
3. "The designation of . . . county or area of residence is not a true function . . . (and) usually require(s) more complex and costly administrative procedures . . . (However, in some) cases . . . (it) may facilitate the accomplishment of the (primary) function . . . (and also) may help in the enforcement of registration laws. . .
4. "The advertising and publicizing of the state is not a function . . . (and) tends to reduce the effective accomplishment of the important functions . . . ." (p. 417-418)

Design considerations drawn from the above functions were as follows:

1. "(E)ach vehicle should be issued two plates . . . .
2. "The . . . registration number . . . should have the greatest legibility distance possible in consideration of plate size and design.
3. "(P)late(s) . . . (should) posses(s) maximum legibility under actual traffic conditions. . . (and be) easy to remember . . . .
4. "The year number should be legible at a distance approximately one-half that of the registration number.
5. "The state name should be legible at a distance slightly greater than that required for reading the year number.
6. "The year number is more important than the color combination . . . . Cooperation . . . among the states is necessary for color . . . to be of great help . . . .
7. "(A)rea designations . . . aid in . . . identification . . . .
8. "(A)rea designations . . . require more complex and costly administrative procedures . . . .
9. "The (area) name is the least popular method of effecting (an area) designation.
10. "The effect of address changes on the value of . . . area designations is slight . . . (when) plates are issued annually. . .
11. "(A)rea designations are of little value . . . outside the state . . . .
12. "(S)logans and emblems may have some value in (state) identification . . . .
13. "(However, ) . . . removal of . . . slogans . . . and the use of the increased space for a larger state name would make state identification easier.

14. "The removal of . . . slogans . . . and the use of larger . . . registration numbers could be a significant improvement . . . ." (p. 418-419)

"The items of information . . . on the plate . . . are the primary design considerations. . . and . . . consis(t) of (a) the vehicle registration number, (b) the name of the state or province, and (c) the year of issuance." (p. 419)

Result (literature search):

1. (plate size and shape) - "(T)he American Association of Motor Vehicle Administrators adopted a standard 6- by 12-(inch) plate size in 1953 . . . (This) has given auto manufacturers an opportunity to provide better mounting . . . to protect (plates) from damage. . . (H)owever . . . the front plate . . . often becomes badly damaged and illegible." (p. 419)
2. (legibility distances) - "The desired legibility distance of the registration number generally ranges from 100 to 150 (feet). Previous . . . studies (see Aldrich-1937, Berger-1944b, and Kuntz-1950, all elsewhere in this volume; as well as the following: License plate visibility tests, Michigan Department of State, mimeo., 1940; T.M. Matson, W.S. Smith, and F.W. Hurd, Traffic engineering, McGraw-Hill, 1955; and C.C. Wiley, Automobile license plates for Illinois, University of Illinois, 1937) have shown that this requires a 2-1/2- to 3-(inch) high character. The state name (and year number) ha(ve) . . . desirable legibility distance(s) of 60 to 75 (feet) which can be achieved with 1-(inch) high (characters). . . Allowing 3/4-(inch) margins above and below the characters, and 1/2-(inch) spacing between the state and identification number, gives a total vertical dimension of 6 (inches). The factors determining length are number of characters, width of characters, spacing between characters, and edge spacing." (p. 420)
3. (number of characters) - "(I)t is never desirable to have more than six total characters in an identification number." (p. 420)
4. (standard characters) - "(T)he Bureau of Public Roads SERIES C Alphabet has a daylight legibility distance of approximately 42 (feet) per (inch) of letter height." (p. 420) (see Matson, ibid.)
5. (plate size) - "Although a 14-(inch) plate is desirable, it does not appear likely that any changes will be made soon in the standard . . . Future changes . . . should be based on . . . legibility distances . . . ." (p. 420-421)
6. (Aldrich on perception of license plate legends) - "For a short observation period (0.67 seconds), 5-digit numbers are decidedly superior to those with 6, and 6- . . . (to) those with 7. Little would be gained by reducing the number . . . to 4. . . (Six)-character plates with 1 letter are more easily perceived than 7-digit plates, and 5- . . . with 2 . . . are better than 6- . . . with 1 . . . ." (p. 421) (see Aldrich-1937)
7. (legibility distance of letters and numbers) - "The desired daytime legibility distance of the registration number . . . is generally in the range of 100 to 150 (feet). . . (see Matson, ibid.) There is a definite correlation between the height

of characters and their legibility. . . that . . . is not linear . . . (see T. W. Forbes and R. S. Holmes, Legibility distances of highway destination signs in relation to letter height, letter width, and reflectorization, HRB Proceedings, v. 19 (1939) 321-335) Regardless of the relationship, an increase in character height results in an increased legibility distance, provided that the width of the character increases proportionately. . . (see Matson, ibid.) The daytime legibility per inch of letter height of the U. S. Bureau of Public Roads alphabets has been reported as follows:

"SERIES B, 33 (feet) per (inch);
"SERIES C. 42 (feet) per (inch); and
"SERIES D, 50 (feet) per (inch). (see Matson, ibid.)

"Soar . . . prescribes 1.33:1 as an optimum height-to-width ratio. (see Soar-1955a) Lauer (in an unpublished memorandum) . . . indicates that the legibility distance increases as the height-width ratio approaches unity. (Thus t)he references . . . suggest the following . . .: (a) the height-to-width ratio . . . is an important determinant in its legibility distance; (b) there is a correlation between the height of a character and its legibility. . . (N)umbers and letters currently used on license plates sho(w) . . . (too large) height-to-width ratio(s) . . . . As a general guide, . . . (it) should be reduced to 2:1 or less . . . It would appear, then, that as long as the standard plate remains 6 by 12 (inches), the letters and numbers . . . should have approximately the following dimensions: height, 2-1/2 to 3 (inches) and width, 1-1/4 to 1-3/4 (inches). . . The optimum stroke width . . . is dependent on . . . height and width, and on the colors of . . . character and . . . background. . . The height (of a character) is measured from the centers of the top and bottom horizontal strokes. . . Kuntz says the optimum (height/stroke width) ratio is 5.0:1, but . . . the difference between 5.0:1 and 6.0:1 or 4.0:1 is not significant." (p. 427) (see Kuntz-1950)

8. (character styling) - "(T)he most important . . . factors involved in the determination of an optimum character styling . . . are

"(a) simplicity or complexity of the character outline,
"(b) amount of open space within the outline of the character, and
"(c) emphasis on one component of the character which differentiates it from another.

"Character styles can be grouped into four general categories;

"BLOCK,
"ROUNDED BLOCK,
"ROUNDED, and
"OPEN.

"Neal says that ROUNDED letters are more visible than BLOCK, and do not tend to run together as much when closely spaced. (see H. E. Neal, The legibility of highway signs, Traffic Engineering, 17:12 (1947) 525-529) Aldrich states that the OPEN style . . . is more visible than either the ROUND or BLOCK. (see Aldrich-1937) According to Matson . . . the ROUNDED BLOCK style letters yield about 5 percent

greater legibility distance than pure BLOCK capital letters. . . (see Matson, ibid.) (T)hose states which use BLOCK . . . or . . . unusual style (characters) should adopt some version of the OPEN or ROUND style. . . (to) elimin-te similarity between characters (BLOCK) . . . and the confusion . . . (in) unusual style(s). . . (S)tyles should be similar to the . . . SERIES B or C . . ., or the American Association of Motor Vehicle Administrators standard alphabet for license plates." (p. 428)

9. (character spacing) - "(S)pacing . . . is an important consideration . . ., and . . . generous spacing is advantageous. . . (License) plate . . . characters (must be) designed so that they all have the same width (except 1 and I) and the same . . . space between the extremities of adjacent characters (again, except 1 and I?). . . The Bureau of Public Roads recommends . . . 1.2 times the stroke width for parallel strokes, to almost zero for strokes of opposing slope. Neu . . . presented a formula for determining the minimum spacing between parallel lines. This formula is

   S (required spacing in inches) = 0.0035D (required legibility distance in feet) . . . (see R. J. Neu, Internally-illuminated traffic signs, Traffic Quarterly, v. 10 (1956) 247-259)

   When reflective (rather than painted) surfaces are used, spacing requirements vary. . . (see Herrington-1960 and Karmeier-1960) (S)pacing . . . on current plates is too small . . . (S)pacing requirements vary with the size and shape of character . . . (F)or a legibility distance of 150 (feet), spacing between characters on painted plates should be approximately 1/2 (inches) . . . (S)pacing of characters on reflectorized plates must be considered separately." (p. 428-429)

10. (relative legibility) - "Kuntz stated that those numerals having the most curved lines are least legible . . . . The order of legibility according to his data was 1, 7, 0, 4, 3, 2, 9, 6, 5, and 8. . . (see Kuntz-1950) Aldrich noted that (1, 2, 4, 5, 6, 7, and 0) . . . were confused least . . . (and) 3, 8, and 9 were confused most. . . (H)e also noted that a 3 with a flat top was found to be . . . easily confused with a 5. . . (see Aldrich-1937) Neu's table of the relative legibility of . . . letters . . . show A, I, L and T to be the most legible, and B, H, and G to be the least. All othe(r letters) are in the group of fair legibility. . . (see Neu, ibid.) The legibility of letters will vary with the letter style, size, and shape . . . (T)here is no conclusive evidence that either letters or numbers are . . . more legible." (p. 429)

11. (special registration systems) - "The use of a classification letter, or letters, for trucks appears to be a satisfactory procedure. As with passenger plates, the letters should be larger than . . . and separated from the numbers. . . (I)t would appear desirable to place the (truck) classification letter(s) . . . at the end of the combination, especially where truck plates are of the same color combination as passenger car plates. . . Special plates should be limited to those types which are absolutely necessary, because they are non-uniform, more costly to manufacture, and cause complex recording systems." (p. 431-432)

12. (color combinations) - Preston reported the following: "'Blue on white, black on

yellow, green on white, and black on white provide good legibility; green on red, red on yellow, and red on white provide fair legibility; and orange on white, and red on green provide poor legibility." (p. 436) (see K Preston, H. P. Schwankl, and M. A. Tinker, The effect of variations in color of print and background on legibility, Journal of General Psychology, v. 6 (1932) 459-461; and reviewed in this volume by Paterson-1940a) The Michigan Department of State reported the following (see Michigan Department of State, ibid.):

| | legibil. dist. (feet) | |
|---|---|---|
| color combinations | day | night |
| white on maroon | 158.4 | 114.0 |
| maroon on white | 145.4 | 102.7 |
| brown on cream | 152.5 | 89.2 |
| cream on brown | 147.8 | 101.4 |
| white on dark green | 152.7 | 102.8 |
| black on white | 146.9 | 107.1 |
| dark blue on maize | 153.7 | 102.8 |
| maize on dark blue | 142.3 | 110.5 |
| dark green on light green | 139.2 | 88.6 |

(above from p. 436)

Wiley reported the following:

1. "'For dark colors, use black and the darker shades of red, blue and green. Avoid the more brilliant shades.
2. "'For light colors use white, the more brilliant shades of yellow and light chrome orange, and perhaps the light tints of green and blue.
3. "'Avoid grays, browns, and other neutral shades. Do not put colors of similar reflecting power or wave length in combination. Thus, red on black is decidedly bad. Yellow on green is not very good unless the green is very dark, etc.
4. "'Dark symbols on light backgrounds appear preferable to the reverse, but, with well chosen colors, the difference is not so marked as to be objectionable." (p. 436) (see Wiley, ibid.)

Outdoor Advertising, Inc. reported the following ranking of color combinations (see Lettering color schemes, Art Department, Outdoor Advertising Inc., Chicago):

"1. Black on yellow
2. Black on white
3. Yellow on black
4. White on black
5. Blue on white
6. White on blue
7. Blue on yellow
8. Yellow on blue
9. Green on white
10. White on green
11. Brown on white
12. White on brown
13. Brown on yellow
14. Yellow on brown
15. Red on white
16. White on red
17. Red on yellow
18. Yellow on red" (p. 436)

General Electric Co. reported the following reflectance values for paints:

| color | reflectance | color | reflectance |
|---|---|---|---|
| black | 0 % | light green | 41 % |
| dark blue | 8 % | tan | 41 % |
| dark green | 8 % | light orange | 53 % |
| dark brown | 15 % | light pink | 62 % |
| red | 22 % | yellow | 66 % |
| orange | 36 % | ivory | 79 % |
| light blue | 40 % | white | 82 % |

(above from p. 436)

"Lauer has suggested that the differences between the reflectance values of colors used for legend and background should be no less than 45 percent. Following this . . ., the following color combinations are suitable for use on license plates (see A.R. Lauer, Certain structural components of letters for improving the efficiency of the stop sign, HRB Proceedings, v. 27 (1947) 360-371):

| color combination | diff. bet. reflect. values (%) |
|---|---|
| black and white | 82 |
| black and ivory | 79 |
| dark blue and white | 74 |
| dark green and white | 74 |
| dark blue and ivory | 71 |
| dark green and ivory | 71 |
| dark brown and white | 67 |
| black and yellow | 66 |
| dark brown and ivory | 64 |
| black and light pink | 62 |
| red and white | 60 |
| dark blue and yellow | 58 |
| dark green and yellow | 58 |
| red and ivory | 57 |
| dark blue and light pink | 54 |
| dark green and light pink | 54 |
| black and light orange | 53 |
| dark brown and yellow | 51 |
| dark brown and light pink | 47 |
| orange and white | 46 |
| dark blue and light orange | 45 |
| dark green and light orange | 45 |

(above from p. 436-437)

13. (area designations) - "The designation of the vehicle owner's . . . area of residence is not a true function of license plates. . . (however) area designations may facilitate the accomplishment of the function of identifying the vehicle quickly and accurately." (p. 438) (see D. Karmeier, An evaluation of the purposes of motor vehicle license plates, Engineering Experiment Station, University of Illinois, 1958)

14. (reflectorized plates) - "Investigations (not delineated here) were conducted to reveal the basic factors concerning the legibility of reflectorized plates . . . The variables studied were as follows:

    a. "Types of reflectorized and nonreflectorized materials:

        (1) Flat sheeting . . . .

        (2) Exposed lens sheeting . . . .

        (3) Beads on paint . . . .

(4) Semi-gloss paint . . . .

(5) Aluminum paint . . . .

b. "Systems of reflectorization:

(1) Background only reflectorized.

(2) Legend only reflectorized.

(3) Both background and legend reflectorized.

c. "Stroke width of characters.

d. "Spacing of characters.

e. "Reflectorized borders.

f. "Color combinations." (p. 438-439)

Procedure - Experiment I (grouping of letters and numbers): 1/2-second exposure followed by immediate recording---indoor---128 slides, illustrating 16 combinations---plates were white, 6 inches high and from 10-3/8 to 13-7/8 inches long---numerals and letters were black, 2-3/8 inches high, 1-3/8 inches wide (except "1" and "I"), with 5/16-inch stroke width---spacing between adjacent characters was 3/8 inches; between groups, 1 inch; and at the edges, 1/2 inch---letters and numbers were centered vertically---no year number, state name, slogan, or insignia---darkened room---500-watt slide projector---Ilex tachistoscope---70- by 70-inch screen---3, 4, or 5 subjects seated 20 feet from screen, at a table, and with data sheet and pencil---1/2-second exposure---50 male, college-student subjects---general form of the combinations tested was as follows:

| | | | |
|---|---|---|---|
| 12 345 | A 1234 | 123 AB | 1234 A5 |
| 123 456 | 1A 234 | A1 2345 | AB 1234 |
| 1234 567 | 123 A4 | 1A 2345 | 1234 AB |
| 1234567 | AB 123 | 1234 5A | ABC 123 |

Result - Experiment I (grouping of letters and numbers): The following results were shown:

| form | rank | percent correct |
|---|---|---|
| 12 345 | 1 | 92.0 |
| A 1234 | 2 | 90.8 |
| AB 123 | 3 | 89.8 |
| 123 AB | 4 | 86.8 |
| 123 A4 | 5 | 83.0 |
| 1A 234 | 6 | 80.4 |
| 123 456 | 7 | 75.0 |
| AB 1234 | 8 | 70.0 |
| 1234 AB | 9 | 58.8 |
| 1A 2345 | 10 | 58.6 |
| 1234 A5 | 11 | 55.6 |
| ABC 123 | 12 | 53.4 |
| A1 2345 | 13 | 51.0 |
| 1234 5A | 14 | 32.8 |
| 1234 567 | 15 | 28.9 |
| 1234567 | 16 | 26.0 |

In comparing combinations which differed only in the number of numerals and the total number of characters, the means differed significantly at the one percent level in favor of the combinations having fewer total characters. In comparing combinations which differed only in the number of letters and the total number of characters, the means differed

significantly at the one percent level in favor of the combinations having fewer total characters. In comparing other combinations, the following significant differences were found (at the indicated level of confidence):

12 345 and AB 123 both significantly better than 1A 234 at the one percent level of confidence.

12 345 not significantly better than AB 123.

AB 1234 significantly better than both A1 2345 and 1A 2345 at the one and five percent levels of confidence respectively.

123 AB not significantly better than 123 A4.

1234 AB significantly better than 1234 5A at the one percent level of confidence but not significantly better than 1234 A5.

(1) 12 345 at 1% over 1A 234
123 456 at 1% over 1A 2345
1A 2345 at 1% over 1234 567

(2) 12 345 not over AB 123
123 456 not over AB 1234
AB 1234 at 1% over 1234 567

(3) 12 345 at 1% over ABC 123
123 456 at 1% over ABC 123
ABC 123 at 1% over 1234 567

(4) AB 123 at 1% over 1A 234
AB 1234 at 5% over 1A 2345

(5) AB 123 at 1% over ABC 123
AB 1234 at 1% over ABC 123

(6) AB 123 not over 123 AB
AB 1234 at 5% over 1234 AB

(7) 12 345 not over A 1234
12 345 at 5% over 123 A4

(8) 1A 234 not over 123 456
123 A4 not over 123 456

(9) 1234 567 not over 1234567
1A 2345 not over A1 2345
1234 A5 at 1% over 1234 5A

Procedure - Experiment IA (supplemental): "(A) limited number of police observers . . . were also tested." (p. 426) The following results were shown:

| form | rank | percent correct |
|---|---|---|
| 12 345 | 1 | 98.7 |
| AB 123 | 2 | 92.7 |
| A 1234 | 3 | 89.4 |
| 1A 234 | 4 | 82.7 |
| 123 AB | 4 | 82.7 |
| 123 456 | 4 | 82.7 |
| AB 1234 | 7 | 82.0 |
| 123 A4 | 8 | 79.4 |
| 1A 2345 | 9 | 58.0 |
| A1 2345 | 10 | 47.3 |
| 1234 567 | 11 | 42.2 |
| ABC 123 | 12 | 40.7 |
| 1234 AB | 13 | 38.7 |
| 1234 A5 | 14 | 36.0 |
| 1234567 | 15 | 30.7 |
| 1234 5A | 16 | 21.3 |

(above from p. 426)

Result - Experiment IA (supplemental): "The (above) results . . . suggest the need for . . . uniformity in the identification systems . . . . All combinations should be properly grouped and spaced, letters should always appear at the beginning or end and be separated from the numbers . . . ." (p. 426)

Procedure - Experiment II (stroke-width): "As a portion of the study of reflectorized plates, the effect of stroke width on legibility was studied for 3-(inch) white (and blue) painted numerals on blue (and white, respectively) painted backgrounds . . . in a darkened indoor area with . . . illuminat(ion from) low beams of a standard headlight system." (p. 427) Stroke-widths used were 7/16, 3/8, 5/16, and 1/4 inches.

Result - Experiment II (stroke-width): The following results were shown:

| stroke width (inches) | legibility distances (feet) white on blue | blue on white |
|---|---|---|
| 7/16 | 112.4 | 107.3 |
| 3/8 | 109.8 | 103.1 |
| 5/16 | 110.2 | 100.1 |
| 1/4 | 109.5 | 98.4 |

(above from p. 428)

"However . . . (c)loser spacing would (probably have) tend(ed) to cause white numbers to merge . . . when their stroke width was large. . . (C)haracters used on painted plates should have a (height/stroke-width) ratio similar to . . . SERIES C . . . . Assuming a height-to-width ratio of . . . 2:1, . . ." (p. 428) the following recommendations are made:

| height (inches) | stroke-width (inches) |
|---|---|
| 2 | 1/4 |
| 2-1/2 | 5/16 |
| 3 | 3/8 |

(above from p. 428)

Procedure - Experiment III (pure legibility): "A pure legibility test, using 20 (6- by 12-inch) test plates bearing either (2, 3, or 4) . . . numbers or . . . letters (in blue on a white ground), was conducted (in a dark indoor area under controlled artificial lighting) to determine the relative legibility of groups of letters and numbers. Numbers used were . . . SERIES B, 3 (inches) high, 1-17/64 (inches) wide, and with a 3/8 (inch) stroke. The letters used were modified SERIES B, 3 (inches) high, with a 3/8 (inch) stroke. The width . . . varied from 1-1/4 . . . to 1-1/2 (inches). All characters were centered on the test plate with 1/2-(inch) spacing between adjacent characters. . . For purposes of comparison, three actual plates were added to the test. . . 3 letters and 3 numbers, black . . . on . . . yellow . . . 2 letters and 4 numbers, black . . . on . . . yellow . . . 2 letters and 4 numbers, blue . . . on . . . gold . . . Test plates were . . . advanced toward the observer at a constant rate of approximately 1 (foot) per (second). The observer . . . read aloud the characters . . . (and) the legibility distance was recorded . . . Two distances (one for numbers and the other for letters) were recorded for the 3 actual plates . . . . Twelve observers (9 male and 3 female) . . . made a total of 312 observations." (p. 429-430)

Result - Experiment III (pure legibility): "The results . . . indicate(d) that numbers in groups of 3 or 4 are legible at a greater distance than letters in groups of 2 or 3. . . The legibility distances of . . . the actual . . . plates substantiate(d) the results . . . Letters used in letter-number combinations must be designed so that they will have legibility distances equal to those of numbers. Wiley has stated: 'For balanced legibility, the letters should be somewhat larger than the numbers.'. . Assuming a linear relationship between legibility distance and letter height, . . . letters in groups of 3 should be 22.5 percent larger than numbers in groups of 3. Similarly, letters in groups of 2 should be 4.0 percent larger than numbers in groups of 4 and 9.7 percent larger than numbers in groups of 3." (p. 431)

Procedure - Experiment IV (state name, year number, and slogans): "Studies of the legibility distance of state names and year numbers of various sizes were conducted . . . (t)o determine (1) the effect of character size on the legibility distance . . . (, ) (2) the correct range of character sizes . . . (, and) (3) the effect of abbreviations on the legibility distance . . . Pure legibility tests . . . conducted us(ed) the 6- by 12-(inch) test plates with white characters on a dark blue background. All plates had a six-numeral registration number, grouped three and three . . . (N)umbers were the Bureau of Public Roads SERIES B . . ., 3 (inches) high and 1-1/4 (inch) wide, with 3/8-(inch) stroke. . . (and) were spaced 1-3/4 (inches) center-to-center, except the third and fourth numbers which were spaced 2-3/4 (inches) . . . . One-half of the plates had full state names and half had abbreviations. One-half of the plates . . . also had abbreviated year numbers. . . Ten observers read 30 plates . . . (in) a total of 300 observations." (p. 433) Apparatus used in previous pure legibility tests was used here.

Result - Experiment IV A (state name and year number): The following legibility distances were found:

| plate | legibility distance (feet) | | | |
|---|---|---|---|---|
| group | reg. no. | state | year | slogan |
| A (0.6 inches) | 115 | 36 | 35 | 39 |
| B (1.0 inches) | 119 | 73 | 66 | -- |
| C (1.5 inches) | 118 | 88 | 81 | -- |

(above from p. 433)

And, in that part of the experiment that investigated state name abbreviations, the following legibility distances were given:

| plate group | legibility distance (feet) full name | abbreviation |
|---|---|---|
| A | 36 | 36 |
| B | 77 | 69 |
| C | 86 | 89 |

(above from p. 434)

From "t" tests run on the results, the following conclusions were drawn:

1. "The height of characters in the state name and year number should be approximately 1.0 (inches) if . . . (they) are to be legible at . . . one-half the legibility distance of the identification legend. . . State names and year numbers on most current designs are too small." (p. 434)
2. "The effect of abbreviations on the legibility of the state name varies with different states.
3. "Omitting the century prefix before the year does not affect the . . . legib(ility distance), but will relieve the crowded appearance of many plates." (p. 435)

Result - Experiment IV B (slogans and emblems): The primary conclusion drawn from the tests was that "(t)he removal of slogans and emblems will permit the use of state names and year numbers large enough to be legible at the distance required for fast and accurate identification." (p. 435) In addition, of motor vehicle administrators and law enforcement officers queried, "(s)eventy-two percent of the law enforcement men and 83 percent of the motor vehicle administrators felt that it would be easier to identify the state if the . . . slogan was removed and the size of the state name increased." (p. 435) Also, "(e)ighty-five percent of the law enforcement officers and 89 percent of the motor vehicle administrators thought that removing slogans to make room for larger . . . registration numbers would be advantageous." (p. 435)

Procedure - Experiment V (contrast): "Legibility studies were conducted to compare the legibility of dark legends on light backgrounds and . . ." (p. 437) vice versa. "The test was conducted in a large indoor area. Plates were illuminated with low beams of a standard 12-volt headlamp system and were drawn toward the observer at a constant speed of about 1 (foot) per (second). All plates carried four numbers, spaced 2-1/2 (inches) center-to-center, 3 (inches) high, 1-1/4 (inches) wide, with varying stroke width." (p. 437)

Result - Experiment V (contrast): The following legibility distances were found:

| stroke width (inches) | legibility distance (feet) white on blue | blue on white |
|---|---|---|
| 14/32 | 112.4 | 107.3 |
| 12/32 | 109.8 | 103.1 |
| 10/32 | 110.2 | 100.1 |
| 8/32 | 109.5 | 98.4 |

(above from p. 437)

From these results, the following conclusions were drawn:

1. "States which adopt permanent color combinations must cooperate with nearby-states to eliminate confusion . . .
2. "Color combinations . . . must have a high . . . contrast . . . . This must be maintained under both natural and artificial lighting.
3. "The relative effectiveness of dark . . . as compared to light backgrounds is

dependent on conditions such as illumination, spacing, stroke width, and color. It is not possible to conclude that either light or dark backgrounds are preferable under all conditions.

4. "Dark colors used . . . should consist of black and the darker shades of blue, green, brown, and red.
5. "Light colors used should be white, ivory, yellow or light orange.
6. "Grey, pink, light blue or green, and other neutral shades, should not be used . . . .
7. "It would appear advantageous . . . to adopt permanent color combinations, reversing the color . . . with each issue of plates." (p. 437)

Result (general): "The results of the perception and legibility studies, together with the results of previous studies, form the basis for the following conclusions regarding identification numbering systems:

1. "A . . . system must be composed of combinations of characters which
   (a) can be perceived quickly and accurately,
   (b) are legible at a (daylight) distance of approximately 125 (feet) . . ., and
   (c) are readily adapted to filing and administrative procedures. . .
2. "(T)he total number of characters should not exceed six.
3. "Combinations of letters and numbers should
   (a) have the letters grouped and separated from the numbers by a space and
   (b) have . . . the letters . . . always appear at the beginning (preferably) or end . . . .
4. "The total number of letters, in a system using . . . letters and numbers, should not exceed 2 unless the . . . registration exceeds the capacity of a 2-letter 4-digit system.
5. "Assuming . . . a registration system using uniform positioning of letters and numbers, and that all digits and letters are used (except Q), the results . . . sugges(t) the following rankings of . . . systems for states of indicated . . . registrations:

   Less than 250, 000
   - a. straight numerical (1 to 250, 000)
   - b. 1 letter, 1 to 4 digits (A 1 to Z 9999)
   - c. 2 letters, 1 to 3 digits (AA 1 to ZZ 999)
   - d. 1 to 3 digits, 2 letters (1 AA to 999 ZZ)

   250, 000 to 500, 000
   - a. straight numerical (1 to 500, 000)
   - b. 2 letters, 1 to 3 digits (AA 1 to ZZ 999)
   - c. 1 to 3 digits, 2 letters (1 AA to 999 ZZ)

   500, 000 to 1, 000, 000
   - a. straight numerical (1 to 999, 999)
   - b. 2 letters, 1 to 4 digits (AA 1 to ZZ 9999)

   1, 000, 000 to 6, 000, 000
   - 2 letters, 1 to 4 digits (AA 1 to ZZ 9999)

   Above 6, 000, 000
   - 3 letters, 1 to 3 digits (AAA 1 to ZZZ 999)
6. "The numbers should be ROUND or OPEN in style, 2-1/2 to 3 (inches) high, 1-1/4 to 1-3/4 (inches) wide, and have a stroke width of 5/16 to 3/8 (inches). The minumum values are for a (standard) 12-(inch) plate; the maximum . . . for a 14-(inch) plate.
7. "The letters should be ROUND or OPEN in style, 2-3/4 to 3-1/2 (inches) high, 1-3/8 . . . to 2 (inches) wide, and should have a stroke width of 5/16 to 7/16 (inches) (for 12- . . . and 14-inch plates, respectively).
8. "For balanced legibility, the letters in a letter-number combination should be 5 to 10 percent larger than the numbers when 1 or 2 letters are used. When 3 letters must be used, the(y) . . . should be 20 to 25 percent larger than the numbers.
9. "Registration systems for . . . special vehicle classes should be chosen from one

of the systems listed in . . . 5 (above), or from one of the following . . .:
(a) 1 to 4 digits, 1 letter (1 A to 9999 Z) and
(b) 1 digit, 1 letter, 1 to 3 digits (1A 1 to 9Z 999)." (p. 432)

2167 * * * Kelly-1960

Kelly, Robert B.

Dunlap and Associates, Inc., Stanford, Conn.

THE EFFECT OF DIRECTION OF CONTRAST OF TV LEGIBILITY UNDER VARYING AMBIENT ILLUMINATION

Jun 60, 12 p., 17 refs.

Contract Nonr 1076(00)

Problem: Determine the effect on the television legibility of black-on-white versus white-on-black characters under three levels of ambient illumination.

Procedure: Twelve subjects (six male and six female, age 22 to 38, each having normal visual acuity and color discrimination) viewed, for 15 seconds each, white-on-black and black-on-white, 20 (14 alpha and 6 numeric) FUTURA DEMIBOLD characters stimuli on a closed-circuit, 675-line television. The 1/8th-inch high characters each covered 5 horizontal scan lines. Ambient illuminations used were 0.026 foot-candles (simulating night-flying conditions), 186.37 foot-candles, and 638.44 foot-candles (approaching simulation of high-altitude daytime ambient lighting). These three levels of ambient illumination gave the following brightness values measured at the screen (in foot-lamberts):

| characters | low | medium | high |
|---|---|---|---|
| white | 16.24 | 31.86 | 56.81 |
| black | 5.68 | 16.10 | 31.97 |

Result: "From examining the simple effects of contrast and ambient illumination . . ., it (was) seen that performance decrease(d) as ambient illumination increase(d) and that white characters (would be) suitable for low (0.026 foot-candles) ambient illumination while black characters (would be) most suitable under high (186.37 and 638.44 foot-candles) ambient conditions. . . The direct application of these results . . . call for:

1. "White characters to be used under such conditions as: night flights, low illuminated 'blind' cockpits of high performance aircraft, and space capsules.
2. "Black characters to be used under such conditions as: daylight flights in the conventional cockpit, high ambient illuminated capsules, and simulator 'mock-ups' in which no canopy masks prevailing ambient illumination.
3. "Inclusion of a mode which provides for changing direction of contrast for use under wide ranges of ambient illumination produced either mechanically (two sets of charts) or electronically (polarity switching technique). . . (p. 11)

"In addition, it is proposed that further investigation be undertaken to study the possibility of negating the differences in performance as a function of direction of contrast by manipulation of the screen brightness and contrast prior to developing a polarity switching device . . . ." (p. i) * * *

2205 Kimura-1959

Kimura, Doreen
McGill U. (Canada)

THE EFFECT OF LETTER POSITION ON RECOGNITION

Canadian Journal of Psychology, 31:1
(March 1959) 1-10 --- (also see Hogg-1957, preceding)

Problem: For the recognition of letters in different parts of the visual field, there are "several questions which may be answered empirically. (a) Is the response sequence the same over a wide range of stimuli, for example, when the letter square is presented with the fixation point at its centre, when gaps and non-alphabetical material are introduced, and when the space between the letters is changed? (b) What is the effect of reading experience? (c) Do changes in the duration of the stimulus affect the way in which letters are reported?" (p. 1)

Procedure: "Mishkin and Forgays . . . found that if English words were tachistoscopically exposed . . ., more words were recognized in the right field than in the left. . . (L)ater . . . Heron . . . demonstrated that . . . (i)f letters are exposed in both fields simultaneously, more letters are recognized to the left of fixation. Heron also found . . . the accuracy with which the letters are recognized . . .: upper left . . ., upper right, lower left, and lower right, in that order." (p. 1) In the three experiments here, the following were found: For the first two experiments, eight samples each of "(t)wenty-four different arrangements of (13 upper case) letters and (8, slightly larger) geometric forms (arranged in squares or rectangles or four in the centers of 3" X 5" white cards so that the mid-point of each letter or form was equidistant from a fixation point) were presented tachistoscopically (30 milliseconds each) to two groups of subjects (40 Army personnel averaging 8 years of schooling, and 20 college students) . . . ." (p. 9) Stimulus groups varied as follows:

1. Group 1 (standard) - letters; visual angles subtended by horizontal distance between letters = $1^{o}56'$, and by vertical distance between letters = $2^{o}22'$.
2. Group 2 - horizontal angle = $4^{o}26'$.
3. Group 3 - horizontal angle = $6^{o}39'$.
4. Groups 4-7 - one letter omitted.
5. Groups 8-13 - two letters omitted.
6. Group 14 - geometric forms only.
7. Groups 15-18 - one geometric form introduced.
8. Groups 19-24 - two geometric forms introduced.

Thus, the specific object of the first two experiments was to determine, for two groups of subjects differing in reading experience (as judged by educational level), "whether the accuracy of recognition was affected by (a) using geometric forms and blank spaces in the letter series; (b) using geometric forms alone as stimuli; (c) increasing the horizontal distance between letters." (p. 2) In the third experiment (designed to determine the

"relation between duration of stimulus and the effect of letter position on recognition . . ."), (p. 5) 56 stimuli (alpha material, similar to groups 2 and 3 above) were presented to each of two groups (N=11 and N=12) of college students at 20 and 40 milliseconds, respectively. For all three experiments, the task was to recognize the letter or symbol and report it on paper, and the test criterion was accuracy.

Result: Experiment I seemed to conform somewhat to Heron's results, except that "(t)he difference between the two upper positions is not significant, but letters in the top positions are recognized significantly more often than letters in the bottom positions, and those in the lower left better than those in the lower right. . . (S)cores for . . . geometric forms and for letters with . . . forms added are in the same order." (p. 3) However, for stimulus groups 2 to 13, "significantly more letters are recognized to the right . . .: that is, the order of recognition is now upper right, upper left, lower right, lower left." (p. 5) Still, it is noticed that "in all these examples more letters are recognized above the fixation point than below it." (p. 5) Experiment II provided a contrast in that for groups 4 to 13, "letters in the upper left are recognized as well as those in the upper right . . .", (p. 5) and for groups 15-24, "the upper left is significantly better . . . ." (p. 5) Thus, in general, "the introduction of gaps or forms is not as disruptive of the order of recognition for the students as it is for the soldiers." (p. 5) Experiment III indicated that exposure time changes the effect of letter position on recognition. However, the "data . . . suggest (differences between positions were not significant for either group of subjects) that, with very short exposure times, the effect may disappear altogether." (p. 7) Probably the clearest conclusions that may be drawn are as follows:

1. "There is a strong tendency to recognize letters in the upper positions more frequently than those in the lower . . ., a difference which is apparent under almost all conditions." (p. 8)
2. "(T)he introduction of gaps and geometric forms seems to have a more disruptive effect with subjects who have had relatively little reading experience than with subjects who have had a great deal." (p. 8)
3. "These results indicate that perception . . . is not a sole function of either retinal locus (to the right?) or eye movement (from the left?) tendencies. It is suggested, instead, that explanation must be some <u>combination</u> of habits acquired during reading." (p. 9)

* * *

3274 Klare-1957

Klare, George R., Nichols, William H., and Shuford, Emir H.
Illinois U., Urbana

THE RELATIONSHIP OF TYPOGRAPHIC ARRANGEMENT TO THE LEARNING OF TECHNICAL TRAINING MATERIAL

Journal of Applied Psychology, 41:1 (February 1957) 41-45, 8 refs.
Contract AF33(038)-25726

Problem: Determine whether "two newly developed methods of typographic arrangement, square span and spaced unit, . . . possess . . . advantages over the usual arrangement. . . (p. 45) One of the chief problems . . . (is that) (n)o rules exist for . . . grouping (by so-called 'thought units') . . . The present study . . . us(es) 'longer' and 'shorter' sizes of units. In addition, it assesses the effects of the experimental arrangements upon reading efficiency, immediate retention, and acceptability of technical material when presented to subjects of a wide range of ability." (p. 41)

Procedure: "Below are sample sentences in (the several) . . . arrangements:

1. Standard:

   The remaining 30 (percent) to 40 (percent) must be dissipated through the cooling system.

2. Square span:

| | | |
|---|---|---|
| The remaining | must be | through the |
| 30 (percent) to 40 (percent) | dissipated | cooling system. |

3. Spaced unit:

   The remaining 30 (percent) to 40 (percent) must be dissipated

   through the cooling system.

"A 1,206-word printed lesson . . . was used in this . . . stud(y). . . (p. 41) (It) was . . . divided (by five people) into thought units . . . The common rules generated by both longer and shorter units were: (a) technical terms consisting of more than one word were not broken into two units; (b) thought units were never arbitrarily broken because of lack of space at the right margin of the paper; and (c) existing punctuation was used and therefore determined units to some extent (i.e., no mark of punctuation was ever used inside a thought unit). . . For the shorter units, the chief rules were: (a) subject and predicate of simple sentences were separated, and object was also separated from predicate; (b) phrases (chiefly prepositional) were set off; (c) noun modifiers, if short, were linked with the noun, and verb modifiers with the verb, but single subjects or objects stood alone; and (d) clauses were set and, if long, broken into appropriate thought units. . . For the longer units, the chief differences were: (a) subject and predicate of short simple sentences were not separated, but object was separated from predicate; (b) phrases were set off, except in short sentences (when they were linked chiefly with the verb); (c) single words at beginning or end of sentences (i.e., used chiefly as subject or object) were joined with adjacent thought units; and (d) short clauses were not broken. . . The subjects used were 533 male airmen in indoctrination training . . . Every fifth line of each version was numbered as an aid in obtaining total number of words read . . . A 50-item multiple-choice test was used to measure immediate retention . . . (p. 42) (Individual) aptitude indices . . . were accounted for in . . . analyses. . . (p. 43) (Q)uestions printed on the back of the answer sheet . . . asked subjects to indicate which was more pleasant to read . . . and four possible reasons: (a) 'is more familiar,' (b) 'is more interesting,' (c) 'is easier to read,' and (d) 'permits faster reading.'" (p. 42)

Result: "The results of this study indicated that . . . square span and spaced unit . . . may possess certain advantages . . . . While square span slowed the reader on first encounter, this effect tended to diminish with practice; spaced unit had little effect upon reading speed. The reader found the newer arrangements less acceptable than the more traditional, but this feeling was less marked when the 'thought units' in the arrangement were small rather than large. The chief effect upon immediate retention produced by the newer arrangements . . . was to provide an increase in test scores for the more able readers. . . (T)he advantages of the newer arrangement(s) are best described as potential, since they interfere with strongly developed reading habits. . . (H)owever, . . . the(y) . . . may be of value for subjects who have had some practice in reading them and/or high ability. Further work in the setting up of thought units was also indicated." (p. 45)

* * *

3334 Klare-1963

Klare, George R.
Ohio U., Athens
THE MEASUREMENT OF READABILITY
Ames, Iowa State U. Press, 1963, 328 p., 48 refs.

Introduction: "This book is primarily a review of research literature (482 annotated items) in the field of readability, together with an analysis of trends and conclusions that can be drawn from the existing data. The term 'readability' has come to be used in three ways:

1. "To indicate legibility of either handwriting or typography.
2. "To indicate ease of reading due to either the interest-value or the pleasantness of writing.
3. "To indicate ease of understanding or comprehension due to the style of writing.

"(R)esearch in each of these areas is legitimately referred to as readability research. . . This book is restricted to the analysis of research stemming from the third meaning. . . Studies of the legibility and interest-value of writing have been excluded, except for occasional studies that also have some relevance to understandability." (p. 1)

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3319 * * * Klemmer-1958

Klemmer, E. T. and Loftus, J. P.
Operational Applications Lab., Air Force Cambridge
Research Center, Washington, D.C.
NUMERALS, NONSENSE FORMS, AND INFORMATION
AFCRC-TR-57-2, Feb 58, 22 p., 10 refs.
Project 7682
AD-110 063

Problem: "How much better are arabic numerals seen and reported than random pattern(s) of lines of about the same complexity? How do numerals and the related class of forms compare with other classes of stimuli when performance is measured in terms of the amount of information transmitted by (a subject)? And, how much more information can (a subject) perceive than he can transmit with the stimuli used in this study?" (p. 1)

Procedure: "A matrix was constructed of individually lighted line segments such that if all lines were illuminated, a block figure 8 would be produced. By selectively lighting only some of the lines, an additional 127 light patterns were generated. . . (A) subclass of ten patterns formed a reasonably good set of the arabic numeral forms. . . (p. 14) Each figure was 4 (inches) high and 2-1/2 (inches) wide. . . (p. 2) Four of the matrices were placed in a row and programmed to produce a random order of the entire class of patterns or, in a separate test, a set of random four-digit numbers. Each pattern was flashed tachistoscopically for 0.02 (seconds).". . (p. 14) from a distance of 30 to 36 feet from the subject. "Ten (subjects) took tests in which they attempted to reproduce the

stimulus patterns on specially prepared answer sheets. In some tests they were asked to reproduce the entire pattern; in other tests a poststimulus cue indicated . . . only that one (of the four matrices) to be recorded. The time between stimulus and cue was varied systematically, and visual and auditory cues were compared. . . Performance was measured in terms of the percentage of line segments correctly reported and . . . of the amount of information transmitted or perceived by (the subject)." (p. 15)

Result: "In the following results, all percentage figures refer to the percentage of line segments reported correctly.

1. "A delay of 0.2 (seconds) between stimulus and poststimulus visual cue gave best performance. The average score was down 7 (percent) with a delay of 3.2 (seconds). A check of two delay times using an auditory cue showed no large difference between visual and auditory cuing.
2. "Performance when a complete report of the four matrices was required was 14 (percent) below performance with the partial response and a 0.2-(second) cue delay.
3. "The arabic numerals were reported only slightly better than nonsense figures when all patterns were mixed.
4. "Several general pattern classifications that emerged correlated with performance. Continuous patterns were seen better than broken patterns. Patterns containing a closed loop of line segments were seen better than patterns without such a loop. Symmetrical patterns were seen better than unsymmetrical patterns. The blank pattern was seen best of all, and patterns of only one line segment were seen better than patterns with more line segments.
5. "An informational analysis of performance showed that the average (subject) transmitted 9.6 bits when the complete response was required, but perceived 17.0 bits as estimated from the best partial response test.
6. "In tests requiring a complete response, the average (subject) transmitted approximately the same amount of information from the arabic numerals as from the complete set of 128 patterns. Practice effects made exact comparisons impossible.
7. "There were large individual differences in relative performance on each of the four positions.
8. "In a controlled association test, the total number of associations given to each pattern by all (subjects) correlated 0.446 with a performance measure.
9. "An average rating score of pattern difficulty by all (subjects) correlated 0.569 with a performance measure.
10. "A large and continuing improvement with practice was observed throughout the 24 days of testing.
11. "Support was found for the hypothesis that information transmission by the human operator varies as the logarithm of display 'coordinality' (defined as 'the number of independent dimensions along which each element of the display varies summed over all independently varying elements' (p. 13))." (p. 15-16)

* * *

2572 Krulee-1954

Krulee, Gilbert K., Podell, Jerome E. and Ronco, Paul G.
Tufts U., Medford, Mass.

EFFECT OF NUMBER OF ALTERNATIVES AND SET ON THE VISUAL DISCRIMINATION OF NUMERALS

Journal of Experimental Psychology, 48:1 (July 1954) 75-80

Problem: "(I)nvestigate (in two experiments) the effect of the number of alternatives and the perceptual set of (a subject) concerning these alternatives on the visual discrimination of numerals. The visual task confronting (subjects is) to discriminate accurately the particular number displayed. The threshold was defined as the maximum distance at which this discrimination was possible. . . (p. 80) Two hypotheses were advanced: (a) that the magnitude of the threshold for discrimination of numerals would increase as the number of alternative possibilities (amount of uncertainty) was increased, and (b) that in a situation in which expected uncertainty exceeded actual uncertainty, the visual threshold would be a function of the number of alternatives expected by (the subject) and not of the number actually used by (the experimenter)." (p. 75)

Procedure: A total of 76, male, naval, enlisted-personnel subjects participated in two experiments; (32 in each of two parts of experiment one and 12 in experiment two) in which they each viewed (through a single eyepiece) 1-inch-high, white-on-black, BERGER numerals in 1-, 2-, and 3-digit numbers, projected in random order onto a frosted glass screen in the rear of a specially designed, 35-1/2-inch long (and 6- by 7-inch square) box. Numerals were behind the screen on a movable carriage controlled by the subject and were illuminated by "light from two shielded 25-(watt) lamps fastened to the box." (p. 75) Subject's task was to permit the carriage to move, from a predetermined zero position, toward the box until "he could recognize the number displayed . . . . The threshold value was defined as the amount of travel required from the initial starting point before recognition was possible." (p. 75) Accuracy was also judged. "The first experiment . . . (specifically) involved the determination of (the) distance threshold under variations in the number of alternatives from which a random selection of presentations was made." (p. 76) While, "(t)he design of the second experiment was chosen so as to investigate the consequences of perceived uncertainty being greater than objective uncertainty." (p. 77)

Result: In the first experiment, "(t)he results for the variable of amount of information corroborate the findings reached by the use of the "t" test. The variation due to information is significant at the 1 (percent) level of confidence for the first half of the experiment (conditions of information used were 2, 4, 8, and 16 alternative categories), but is not significant even at the 5 (percent) level . . . for the second half (16, 32, 100, and 1000 categories)." (p. 77) In the second experiment, "(f)or all variations, there are sharp drops in thresholds, all significant at the 1 (percent) level. . . In contrast . . . the differences in threshold obtained for comparison of the average of the first set of four

presentations as compared to the second set . . . (gave no) differences . . . significant at the 1 (percent) level, and only one at the 5 (percent) level. . . (C)omparisons between the three variations. . . discloses no significant differences . . . (T)hese . . . results are consistent with the . . . finding of no increase in threshold for amounts of information in excess of eight categories." (p. 79) Thus, in general, "(t)he results indicated that the difficulty of (the) perceptual decision varied directly with the number of possible alternatives within the limited range of not more than ten categories. . . In addition, . . . (i)t was shown that thresholds obtained under . . . conditions (of expected uncertainty greater than actual uncertainty) exceeded those obtained when full knowledge was available to (a subject) as to the actual set of alternatives." (p. 80)

* * *

2206 Krulee-1955

Krulee, Gilbert K. and Weisz, Alexander
Tufts Coll., Medford, Mass.
STUDIES IN THE VISUAL DISCRIMINATION OF
MULTIPLE-UNIT DISPLAYS
Journal of Experimental Psychology,
50:5 (November 1955) 316-324

Problem: Experimentally examine the following two general hypotheses:

1. "(I)n single-unit displays, the magnitude of a distance threshold for the recognition of elemental symbols is directly related to the amount of information involved in the recognition of that particular symbol.
2. "(T)he recognition of multiple-unit displays involves independent and concurrent processes such that the distance threshold is primarily a function of that position in the display containing the most difficult discrimination." (p. 323)

Specifically, determine the "distance thresholds for 1-, 2-, and 3-digit displays as a function of the number of alternative possibilities in each position of the display." (p. 324)

Procedure: "In (the) first experiment, the amount of information displayed was held constant, but the coding of the categories was manipulated so as to vary the distribution of information amongst the three possible positions in the display. The (specific) hypothesis advanced was that the distance threshold would vary directly with the number of categories possible in the most complex position of the display." (p. 317) For this experiment, nine sets of "eight categories (or groups of numbers) were defined in terms of 1-, 2-, and 3-digit codes using different choices of elemental symbols to define three such sets of codes." (p. 324) There were eight presentations of each condition to each of nine subjects. Numerals used for this and the following experiment were those designed by Berger and were one inch high. In the second experiment, an "inference that can be drawn from the initially stated hypothesis is that the threshold for 2- or 3-digit numbers should be the

same as that obtained for 1-digit numbers, provided that the discrimination required in the 10's or 100's position does not exceed in complexity the discrimination required in the digits position. . . Similarly, if the discrimination required at each position in a multiple-unit display is limited to a binary choice, then the threshold obtained for a 3-digit binary number should not exceed that obtained for the same binary choice when confined to a single position display." (p. 319) For this experiment, "thresholds for several binary choices (defined by the pairs of numbers: 1 & 8, 1 & 2, 0 & 3, 5 & 9, 4 & 6, and 2 & 7) used both as 1-digit and as 3-digit displays were obtained." (p. 324) There were eight presentations of each of twelve conditions to each of twelve subjects. The third experiment was conducted to ascertain the truth of the following: "With a set of symbols containing a number of elements in excess of 10, it could be predicted that the threshold would increase as long as increases in number of possible categories were accomplished by use of a single unit display." (p. 320) However, since "(i)t is conceivable that (variations due to the perceptual difficulties of symbol discriminations present in experiment three) tend to obscure the effect of amount of information and thus . . . interfere with the main purpose of the experiment", (p. 321) experiment four was carried out to determine if "it should be possible to obtain increases in threshold with each increase in the size of the set of elemental symbols to be discriminated." (p. 322) Thus, for these last two experiments, "an alphabet of 32 symbols (26 letters in a sanserif GOTHIC one inch high and having a height to stroke-width ratio of 5 to 1, with matching numerals 2 through 7) was used in order to investigate the relationship of threshold magnitude to amount of information, provided that only single-position displays were used." (p. 324) Experiments three and four each utilized sixteen subjects; experiment three in one group to determine distance thresholds for conditions of 4, 8, 16, and 32 categories; and experiment four in two groups of eight each to determine distance thresholds for conditions of 8 and 16, and 16 and 32 categories. Visibility threshold was the test criterion for all four experiments.

Result: Experiment one - "With two of the three (major) sets, results . . . indicat(ed) that (the) threshold is directly related to the amount of information contained in the most complex of the three positions. For the third set, the apparent difficulty of the specific binary choice (2 & 7) chosen for the 3-digit code made this the most difficult of the three codes in the set." (p. 324) Experiment two - "With five out of six . . . comparisons no significant differences could be detected for the 3- vs. the 1-digit binary choice." (p. 324) Experiments three and four - "Increases in threshold were obtained in 8 vs. 16 and 16 vs. 32 categories when the comparison was based upon the discrimination of a set of alternatives first in isolation and finally as part of a larger set of alternatives. (However) (t)he data indicate that such threshold increases are not necessarily obtained when the larger set does not contain as members the specific symbols included in the smaller." (p. 324) Experiment four specifically confirmed "the hypothesis relating the magnitude of the distance threshold to the number of possible alternatives . . . for a display limited to the presentation of single-unit symbols." (p. 323) The following general conclusions were drawn:

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1. "One clear-cut implication of all these findings is that hypotheses concerning distance thresholds must involve not only the number of alternative possibilities but also the specific difficulty of discriminating among the elements chosen to define a set of possible alternatives." (p. 323)
2. "It would appear to be desirable if a broader theory of the visual discrimination of symbols could be developed which would include both types of variables and which would increase the predictive value of the existing theories of visual displays." (p. 324)

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3340 Krzhivoglavy-1962

Krzhivoglavy, Yaro
Scientific Research Inst. of Work Safety,
Prague (Czechoslovakia)
ENGINEERING PSYCHOLOGY AND WORK SAFETY
Voprosy Psikhologii (Problems of Psychology),
No. 4 (July-August 1962) 89-98, 12 refs.
Translation in JPRS-17, 219, "Soviet Psychological
Reports-USSR," 21 January 1963, p. 19-30.
Washington, D. C., Joint Publications Research Service.
AD-407 228

Problem: "(I)nvestigat(e) the problem of interpolating readings within the limits of a scale's division (5), and . . . of legibility of different types of figures (10)." (p. 20) Also, "stud(y) the effect of the space surrounding (a control panel) indicator on the accuracy and speed of information reception." (p. 22) Fourth, study the man-machine, visual-communication channel. Fifth, design and propose "a unified three-stage (industrial safety) warning system . . . ." (p. 25) And finally, study "the legibility of road signs." (p. 28)

Procedure (scale divisions): "It was established that the accuracy of interpolation depends on the number of the scales intradivision (division range)." (p. 20)

Result (scale divisions): "(Ninety-six percent) of the accurate readings were observed when the division range of the scale did not exceed 5 interdivisions (the size of one interdivision was 6 minutes). This fact (made) it possible to determine the magnitude of scale divisions and the magnitude of the scale or dial, considering the maximum accuracy and speed of reading indicators." (p. 20)

Procedure (legibility of numerals): Figures used in the experiment were (1) the MACKWORTH, (2) the GILL, and (3) the CHSN 902341, TYPE 1 (Czechoslovakian standard). Of these, "(t)hree significant numbers of (the above) types were displayed . . . (in) a

modified Neylor tach(i)stoscope (at 1/125 second each) to a group of twenty men." (p. 21)

Result (legibility of numerals): "(A)n important difference was observed . . ., which was not of a random nature. On the basis of a T-test it was found that the GILL number type was the most legible . . . The differences . . . are conclusive." (p. 21)

Procedure (control panel design): "(S)ubjects were shown a 'panel' with a complex of conventional symbols (3X3). . . (and) had to find pairs of symbols . . . occupying an identical position. The space surrounding the 'panel' was purposefully changed in different series. . . (p. 22) In the first series the space was homogeneous and unbroken. In the second series, the symbols were moved in the surrounding space in a pattern similar to the symbols of the 'panel.' Also, the 'neutral' external symbols were separated from the basic (meaningful) ones by a special line. In the third series, as in the second, the space surrounding the panel was filled with 'neutral' symbols with the difference that the line separating the basic and 'neutral' symbols was absent." (p. 24)

Result (control panel design): "(T)he presence of symbols in the surrounding space which were similar in form to the meaningful ones significantly lowered the speed and accuracy of fulfilling the task." (p. 24)

Procedure (visual communication channel): "(A)t the place of work in the control room, we determined the amount of information transmitted from the boiler screen and control panel. . . (T)he variety of situations arising in the condition of the apparent indicator organs was an impressive figure -- $10^{436}$. The amount of information transmitted by a determined position of indicator organs was 1460.3 beats." (p. 24)

Result (visual communication channel): "(M)easurements . . . conducted before and after (work) shifts . . . resulted in established significant individual differences, and the total average capacity of transmission (channel of communication) was 8.79 beats (per second). . . A comparison of the capacity of the visual channel of communication and the information load of the indicator organs showed that . . . in transmitting emergency information, at least 164 seconds are required. If one considers that random non-signal charges of indicator organ position is 31.72 beats (per second), it becomes clear that a reduction in the amount of transmitted information is essential to creating optimal working conditions . . . (A) reduction to some degree can be accomplished . . . at the sources of information. . ., for example, (by) designating the inclination tolerance of . . . pointers. Secondly, of no less importance is the study of psychological forms of reducing information." (p. 24-25)

Procedure (warning system): Color, shape and symbolic devices were desired for the following three stages of warning systems:

"Stage I - Sources with a small amount of information. The degree of danger is not a constant magnitude and therefore may be divided into categories. In

practice, a dich(o)tomous division is used most frequently." (p. 25)

"Stage II - Sources with an average amount of information. It is essential to emphasize that the dichotomous designation of dangerous and non-dangerous locations by (e.g.) various colorations cannot completely satisfy us." (p. 26)

"Stage III - Sources with a heavy information load. . . (w)hen it is necessary to transmit safety information in as much detail as possible . . . ." (p. 26)

Result (warning system): The following were devised for each stage:

Stage I - From psychological research, "we devised a system for color designations of places which may involve danger or risk. . . In the most generalized terms, our system . . . takes the following form. Danger is designated by 'warm' colors: red -- stop, orange -- serious danger, yellow -- caution. For designating non-dangerous situations we use 'cold' colors: green -- safe condition, azure -- organizational messages. . . We developed this general system into a complete series of general government standards. Sample standards: 'Colors for transportation light signals' (CHSN 012728), standard of 'shades and paints for textile machines' (CHSN 268810), etc." (p. 25)

Stage II - "(C)onsidering the . . . capability of the human eye to differentiate colors, it would be permissible to select . . . shades of colors . . . . However, there are familiar difficulties here . . . . We therefore chose another way -- combining the danger colors, with a (s)imple geometric form and graphic symbol into one expressive complex. . . We also studied the role of framing warning signs and the size of the background surface. . . (E)xperimental results showed that even the smaller frame improves a sign's legibility. If the frame's surface is increased, the 'reading' accuracy of the sign is increased. A sufficiently large background surface behind the symbol also improves the legibility of warning signs. . . Considerable attention . . . was devoted to the sign legibility in relation to the color and background of the symbol. In this connection we compiled . . . pairs of contrasting colors where combinations of chromatic and achromatic colors were used. . . We tested to see . . . whether sign legibility depends on the background color of the selected pair of colors or the degree of brightness, determined by the reflectability of a colored surface. The results showed that . . . a brightness contrast plays a dominating role in the legibility of various combinations of chromatic and achromatic colors. . . All . . . warning signs . . . devised. . . have been standardized in Czechoslovakia." (p. 26-27)

Stage III - "(T)he best form for this is a warning sign (stage II) with an adjoining text (warning board). . . (I)n designing the indicated source of information we utilized data established in (a previous) investigation of the legibility of

various types of letters and numbers." (p. 28)

Procedure (highway signs): In "determining the legibility of existing road signs. . . we conducted experiments with twenty subjects to whom various road signs were shown at distances from 350 meters (maximum) to 20 meters (minimum). The 'reading' accuracy was recorded. . . (N)ew road signs. . . were subsequently tested . . . on the highways . . . . The type of materials used for painting . . . signs were also . . . experimentally tested." (p. 28-29)

Result (highway signs): "This work resulted in the introduction of paraflex road signs on Czechoslovakian highways." (p. 29)

Result (general): "(I)n attempting to utilize psychology for solving . . . problem(s), we often are at a loss because of not knowing the appropriate psychological features which ought to be taken advantage of in a given case. In relation to work safety, this concerns such problems, for example, as the accuracy of visual interpolation within the range of two hard points, the effect of non-signal stimuli, the effect of surface background size on symbol legibility, psychological means of reducing information, etc. . . The solution of this problem lies in the . . . inclusion of psychology into the complex of other sciences." (p. 29)

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2168 Kuntz-1950

Kuntz, James E., and Sleight, Robert B.
LEGIBILITY OF NUMERALS: THE OPTIMAL RATIO OF HEIGHT TO WIDTH OF STROKE
American Journal of Psychology, 63:4
(October 1950) 567-575, 12 refs.
Rept. no. 166-1-106, Special Devices Center
Contract N5-ori-166
Also in READINGS IN EXPERIMENTAL INDUSTRIAL PSYCHOLOGY,
Milton L. Blum, Editor, (New York, Prentice-Hall, 1952) p. 289-295, 12 refs.

Problem: Determine the most legible numeral height to stroke-width ratio under conditions of varying distance, brightness, and background.

Procedure: Fourteen university student subjects, 20-35 years of age, of normal visual acuity, binocularly viewed LEROY test numerals through a tunnel eight feet long by two feet square. Brightness was varied between 3 and 31 foot-lamberts. Distance from subject's cornea (with head at rest) was ranged inward from two meters, until all numerals were identified. Background was both black on white and vice-versa. Height to stroke-width ratio was varied between 3.5 and 6.5 to one.

Result: The following statements are pertinent:
1. In legibility distance, there seemed to be a consistent, not satistically significant, superiority for black numerals on a white field.
2. Optimal height to stroke-width ratio for legible distance seems to be between four and six to one with a peak (more pronounced for black on white) at about 5:1.

3. There is a consistent trend for legible distance to increase with increasing illumination, with optimal height to stroke-width ratio remaining approximately the same.
4. Legibility of the numerals seemed to be as follows (in descending rank): 1, 7, 0, 4, 3, 2, 9, 6, 5, and 8. This may possibly indicate the need for redesign of low-ranking numerals to improve their legibility.

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2670 Lansdell-1954

Lansdell, H.
Defence Research Medical Labs. (Canada)
EFFECT OF FORM ON THE LEGIBILITY OF NUMBERS
Canadian Journal of Psychology, 8:2 (June 1954) 77-79, 7 refs.
Superseded by P. J. Foley (Defence Research Medical Labs., Canada),
EVALUATION OF ANGULAR DIGITS AND COMPARISONS WITH A CONVENTIONAL SET,
Journal of Applied Psychology, 40:3 (June 1956) 178-180

Problem: Test the legibility of a newly designed, blocked NEW ANGULAR FORM, numeric character set by experimentally comparing it with two, more conventional sets.

Procedure: Six subjects individually viewed black-on-white, 1/4-inch-high digits in three numeric character sets at a distance of 14 feet. Each digit was illuminated at about 10 foot-lamberts for 0.6 seconds by a shaded photoflood bulb in a dark box, 2 x 2 x 3 feet long. The subject controlled the beginning of each exposure by push-button activation of an electronic timer. Room illumination was by overhead, indirect fluorescent tubes. Subjects wrote down the digits, as they were shown, on a record sheet. Each subject was tested on 600 individual digits, with 200 each from the MACKWORTH, MOUND, and NEW ANGULAR FORMS sets, randomly arranged in groups of 100. Accuracy was the test criterion.

Result: "No difference in legibility was found between the MACKWORTH numbers and the MOUND revision of them. All . . . (subjects) did better on the NEW ANGULAR FORMS, which (gave) a (0).03 significance level with the Friedman chi-square test of rank." (p. 78) This better legibility "may be related to the fact that they were presented singly . . . . The difficult viewing conditions (imposed in order to reduce the number of observations necessary to obtain confusion data for further work on the design) may also have been partly responsible for better legibility . . . ." (p. 79) Thus, the NEW ANGULAR FORMS numeral designs, which broke away from the uniform stroke-width tradition by making use of "more easily discriminated form (squares and triangles) components . . . proved to be better than an accepted standard set, when presented singly under difficult viewing conditions." (p. 79)

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2669 Lauer-1948

Lauer, A. R.
Iowa State Coll., Iowa City
CERTAIN STRUCTURAL COMPONENTS OF LETTERS FOR
IMPROVING THE EFFICIENCY OF THE STOP SIGN
In PROCEEDINGS OF THE TWENTY-SEVENTH ANNUAL MEETING,
1947, Roy W. Crum, Fred Burggraf, and W. N. Carey, Jr., Editors,
(Washington, D. C., Highway Research Board, National Research Council,
1948), p. 360-371, 10 refs.

Problem (general): Based upon previous work done by the author and others, as reviewed in the early part of the paper, study the most efficient form of STOP sign.

Problem (experiment 1---Differential Perceptibility of Certain Letters): "(D)etermine the differential perceptibility of the standard SNELLEN letters S, T, O, and P used for visual tests under controlled conditions." (p. 365)

Procedure (experiment 1): "Th(e) letters (were) square with a stroke of 20 percent the width of the letters. The criterion used for vision charts is that each member of the letter subtend an angle of 1 minute and the characters as a whole subtend an angle of 5

minutes. . . The Clason Acuity Meter was used for testing . . . (f)ifty-five observers . . . ." (p. 365)

Result (experiment 1): "The differences were all significant except in the case of O and P which was borderline." (p. 365)

Problem (experiment 2---The Optimal Spacing of BLOCK Letters): Determine the relation of stroke-width to spacing and legibility.

Procedure (experiment 2): In "(a) preliminary check . . . (i)t was found that strokes above 25 percent . . . or less than 18.75 percent of the width were inferior." (p. 365) Then, in the experiment, "(f)ive plates with the word STOP in one-inch letters were constructed using spacings 1/4, 1/2, 3/4, 1 and 1-1/4 (inches) respectively and two widths of stroke, 0.187 and 0.250 percent of the width. BLOCK letters were carefully drawn and inked with India ink. They were mounted on white cardboard . . . for use in the Stoelting Flash Card Tachistoscope . . . for slow-timed exposures. Twenty-three subjects were used . . . The projected light was gradually increased on each test card until the test object was just legible to the observer." (p. 365)

Result (experiment 2): "No very significant difference in spacings were noted for maximum legibility unless it be a slight advantage at about 3/4 (inches), for letters one inch high. No other reason than scotopic vision can be given . . . for the results obtained from 1/4-(inch) stroke which has usually been inferior. . . It may be tentatively concluded that a stroke of 0.25 percent of the width of SQUARE letters is most desirable for very low levels of illumination. . . (T)his result may possibly be explained by a halation effect on the retina, giving in reality a wider effective stroke, while the reverse would hold for black letters on a light reflectorized background." (p. 366)

Problem (experiment 3---Optimal Background-Letter Combinations): "(C)hec(k) the effects of black letters on white background against white letters on dark background with other conditions being held constant." (p. 366)

Procedure (experiment 3): "Identical sets of one-inch BLOCK letters were constructed with backgrounds reversed (black-on-white and white-on-black) using spacings varying from 1/2 to 1-1/4 (inches) and with strokes 3/8 and 1/4 (inches). Two different groups of observers (91 in one and 56 in the other) were used . . . The same apparatus as described in (experiment) 2 was used." (p. 366)

Result (experiment 3): "The results in general lead to the general conclusion that for low levels of illumination, or scotopic vision, wider strokes are necessary than for photopic vision. . . (T)he results . . . of a stroke of about 0.183 of the width for BLOCK letters, hold only at the higher levels of lighting. The superior results obtained by Neal (1944) from white reflectorized letters on black background probably are due to retinal irradiation of the luminous letters giving the effect of a broader stroke which offsets the disadvantage of white on black found in this study. . . Black letters on white were superior in practically all combinations used, the average . . . being about 20 to 25 percent. Spacing between letters is a function of several variables but can probably range between 50 to 100 percent of letter width without doing violence to most letter combinations." (p. 367)

Problem (experiment 4---Optimal Letter Shapes): "(T)est . . . the various styles and sizes of letters to be used as a basis for the final selection of letters to be made for the word STOP in further studies." (p. 367-368)

Procedure (experiment 4): "The same general methods were used to separate letters of the various combinations of styles and characteristics as were made in the previous

(experiments) described. Some modifications of letters were made to test their legibility value." (p. 368) Apparatus was the "(s)ame as that (used) in (experiments) 2 and 3." (p. 368)

Result (experiment 4): "The results were synthesized into a generalized STOP . . . (as) shown . . . . Further modifications will need to be made for reflectorization and fitting on to the background . . . selected. The height may be increased but with diminishing returns in . . . legibility. . . ROUNDED letters with height and width equal, having a stroke of 25 percent of the letter width, and spaced 50 percent of the width . . . , seem(ed) to give the best legibility under conditions of low illumination." (p. 368)

Problem (experiment 5---Relative Perceptibility of Sign Shape and Color): "(D)etermine possible modifications, shapes, and colors, which will give maximum attention value and provide for maximum legibility of the legend on a STOP sign." (p. 368)

Procedure (experiment 5): "The first step was to study the octagonal sign and consider its possibilities. Since only 40 percent of the height of the revised sign is utilized, five possibilities for modifying the shape were considered. Two of these were modifications to form a CROSS, by notching the diagonal corners. One was an OCTAGON having a height of 80 percent of the width while two were modified forms of a sign 60 percent as high as broad. Thirty-six miniature blank signs embracing nine patterns one inch across were constructed from white cardboard and three colors of Scotchlite; white, yellow, and red. These were presented individually to six trained subjects to ascertain at what point the shape and color could be perceived accurately. . . The apparatus (was) the same as that described in . . . experiments . . . 2, 3, and 4." (p. 368)

Result (experiment 5): "In very low levels of illumination (below 0.01 to 0.40 foot-candles) the yellow reflecting surfaces were difficult to discriminate from white. This . . . resulted in higher light readings for both white and yellow, than would normally result if discrimination of only white and red were made. . . In general, . . . the DIAMOND and SQUARE are easiest to discriminate while the most difficult are the CIRCLE and OCTAGON. As the OCTAGONAL shape is decreased in height it becomes easier to distinguish from the CIRCLE and to be identified as a characteristic shape. . . Red (was) easiest to distinguish as a color but this experiment did not indicate clearly whether it showed up equally well at very low levels of illumination." (p. 368-369)

Experiment 6 (based on the question "When reflectorizations are used, how will this modify the results obtained on painted signs") (p. 364): This experiment was not included in the paper.

Problem (experiment 7---Comparison of Thresholds for Visibility, Color, and Shape): "(D)etermine which of four types of reflecting and plain surfaces were easiest to perceive; (a) as an object, (b) as a shape, and (c) as a color when relatively large areas were exposed, well above the angle of normal visual discrimination." (p. 369)

Procedure (experiment 7): "The same laboratory apparatus and technique were used as in (experiment) 6 with shapes 5 (inches) across being exposed at 20 (feet) and four trained subjects making a total of 78 observations." (p. 369)

Result (experiment 7): "The results . . . suggest strongly that STOP signs should carry some combinations of white and red reflectorized materials since yellow does not have a low color visibility threshold. No valid conclusions can be drawn on shapes . . . . Color vision may in some degree affect the ultimate choice of colors. . . (and) seems much more critical at low levels of illumination . . . ." (p. 369)

Problem (experiment 8---Comparison of Laboratory and Outdoor Results on Typical

Signs Used): Make a preliminary evaluation of a series of model signs constructed of experimental forms.

Procedure (experiment 8): "To make preliminary evaluations of the experimental forms of STOP signs shown, tests were made with . . . laboratory apparatus at 20 (feet) and with the signs outdoors in 300 to 400 (foot) candles of light on a hazy afternoon. They were set in mild shade with the surface facing the west for the outdoor runs. . . Two trained subjects were used . . . ." (p. 370)

Result (experiment 8): The following rank was obtained for the signs shown (best to worst):

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 20 feet | 2 | 6 | 4 | 1 | 5 | 7 | 3 |
| distance | 4 | 7 | 6 | 1 | 2 | 3 | 5 |
| combined | 2 | 7 | 5-1/2 | 1 | 3 | 5-1/2 | 4 |

(above from p. 370)

"Some of the designs shown would be more effective if the letters weie taller but they represent specimens of types to be reflectorized for further study." (p. 371)

Result (general): "It was found the ROUNDED letters are superior and that the letter T needs to be strengthened to make it equal to other letters as a part of the STOP Gestalt. Strokes of about 25 percent of the letter width were found best. Ovalizing the O seems to improve it as an individual letter as well as improving the Gestalt of the STOP sign generally. . . Preliminary studies of background colors and shapes show(ed) a superiority of horizontally elongated OCTAGONAL signs for discrimination of form. As a distinctive target the reflectorized red seems to have an advantage over yellow. Earlier experiments would indicate the reverse to be true for non-reflectorized signs although this result might have been suspected on theoretical grounds. . . The results show that the efficiency of standard signs now in use can be improved from 20 to 50 percent by redesign of the letters. Target value of the OCTAGONAL form, as a precautionary sign, could be much improved by a change in shape. . . Probably the most effective as well as distinctive STOP sign from all points of view (would) be a combination of red and white reflectorized materials with a third color or material used for letterings." (p. 371)

* * *

2171 Legros-1916

Legros, Lucien A. and Grant, John C.
TYPOGRAPHICAL PRINTING-SURFACES
London, Longmans, Green & Co., 1916, 732 p.

Extract: "(T)he aim having been not only to produce an interesting volume, but to make it also a standard text-book (manual of technology) on . . . the art of producing a (typographical) printing-surface . . . ." (p. xi & v) The following outline of contents, with emphasis on chapters that are outlined in detail, shows the scope of this rather extensive typographic design manual:

Introduction (including notes on historical origin), and Preface (including raison d'etre). Glossary of common technical terms (referenced to the text).

1. Printing-surfaces (intaglio, lithographic, and relievo).
2. Typography (the art of writing by means of movable types).
3. Description of type.
4. Typefounding (history and current practice).
5. Type design.
   a. Principles (including optical illusion, of which figures 25 through 40 are examples).

b. The influence of illusion on the form of characters (including figure 41---alinement and peculiarities of type).

c. The influence of the serif (including samples of the following type faces: canon CONDENSED SANS, 30-point CONDENSED SANS SERIF, 2-line great primer GROTESQUE NO. 4, 30-point ANTIQUE NO. 3, 2-line english 27-point FRENCH ANTIQUE, 36-point IONIC, 36-point VENETIAN OLD-STYLE, 2-line great primer ANTIQUE NO. 8, 36-point OLD-STYLE, 36-point HADDONIAN, 2-line english 27-point OLD-STYLE ANTIQUE NO. 7, 2-line great primer OLD-FACE, 3-line pica DE VINNE, 2-line GREAT PRIMER NO. 4, and 24-point ATLAS).

6. Founts of type.

a. Conventional founts (including table 1 which shows the 275 characters in the ordinary fount of type, a listing of 76 additional characters used in languages based on the LATIN character, and figure 42---INTERNATIONAL PHONETIC ASSOCIATION type).

b. Conventional and ideographic signs (including samples of the following: ASTRONOMICAL SIGNS; PSEUDO-SCIENTIFIC SIGNS; MATHEMATICAL SIGNS and the interrelationship between typesetting and mathematical composition showing also figure 43---example of mathematical composition and cross-section through the component type, ECCLESIASTICAL SIGNS, MEDICAL SIGNS, ARCHEOLOGICAL SIGNS; SCRIBAL ABBREVIATIONS, CARTOGRAPHICAL SIGNS; NATURAL HISTORY SIGNS, BOTANICAL SIGNS, MONEY SIGNS; COMMERCIAL SIGNS, METEOROLOGICAL SIGNS, WEIGHTS and MEASURES SIGNS; ENGINEERING SIGNS, PEDIGREE SIGNS; CROWNS, CORONETS, WREATHS, HELMETS, and HERALDIC SIGNS, ORDERS, MEDALS, MASONIC, and other SECRET and PHILANTHROPIC ASSOCIATION SIGNS, POLITICAL SIGNS; METAL SIGNS; TRAVEL SIGNS, DIRECTION SIGNS, CAUTION SIGNS; SPORT SIGNS; MISCELLANEOUS SIGNS; and SYMBOLIC SIGNS with an example of use of symbolic signs in contemporary work).

7. Units and dimensions.

a. Spaces and quads.

b. Height-to-paper.

c. Units (including table 2---pica sizes, a chart of sizes above double pica, table 3---body-sizes of type, table 4---faces and body-sizes, typographic points including figures 44 through 49---facsimile reproduction of Fournier's table of proportions of body-sizes, the Didot point system, and other systems including Fergusson's Rules and table 5---Shanks's point system).

d. Accuracy of body and set (including limits of accuracy, figure 50---single-ended body-gauge for type, table 6---comparative table giving names of English and foreign type and their dimensional relationships in Fournier-Didot- and standard-points in inches and in millimeters, tables 7 and 8---set widths of modern and old-style pica founts without spaces and quads, and figures 51 through 55---various gauges).

e. Self-spacing type (including table 9 which shows the set widths of 281 characters and spaces).

f. Kerning and bearding (including figures 56 and 57---kerned type as cast and after dressing).

8. Type faces.

a. Variety of faces (classified as old-style, e.g. PICA OLD-STYLE; modern, e.g. PICA MODERN; and fancy, e.g. BLACKFRIARS, faces). The chief varieties are as follows: BLACK, BLACK ECCLESIASTICAL (both of which were formerly referred to as GOTHIC), SANSERIF (sometimes called SANS, SANS SERIF, GROTESQUE, or GOTHIC, and in its italic form is prefaced by the adjective INCLINED), OLD-FACE, OLD-STYLE ANTIQUE, DE VINNE, BLACKFRIARS, CHELTENHAM, LATIN (sometimes called ANTIQUE), MODERNIZED OLD-STYLE, MODERN, and ANTIQUE (sometimes called CLARENDON or EGYPTIAN, and has the derivatives IONIC and FRENCH ANTIQUE). Figures 58 through 60 show "the sorts . . . arranged in tabular form for capitals, lower-case, figures and points, and for italics where such are used . . . ." (p. 88) Specific faces shown in these figures are as follows: BLACK, TUDOR BLACK (ECCLESIASTICAL), SANSERIF, OLD-FACE, ANTIQUE OLD-STYLE, DE VINNE, BLACKFRIARS, CHELTENHAM OLD-STYLE, BOLD LATIN, MODERNIZED OLD-STYLE, MODERN, EGYPTIAN, INCLINED SANSERIF, OLD-FACE ITALIC, DE VINNE ITALIC, BLACKFRIARS ITALIC, CHELTENHAM OLD-STYLE ITALIC, MODERNIZED OLD-STYLE ITALIC, and MODERN ITALIC.

b. Width of face (including figure 61, which shows the following faces and their a-z em-lengths: EXTRA CONDENSED, CONDENSED, LEAN, STANDARD, FAT, BROAD-FACED, and EXPANDED; and figure 62---comparison of a-z lengths of the following 60 type founts: nonpareil BLACK NO. 3 and TUDOR BLACK; long primer BLACK NO. 1, AUGUSTAN BLACK, and OLD-STYLE ANTIQUE NO. 3; brevier OLD-STYLE ANTIQUE NO. 7; minion on brevier ANTIQUE; brevier ITALIAN; pica and bourgeois OLD-STYLE; brevier OLD-STYLE ANTIQUE NO. 8; pica and brevier MODERN; 22 long primer ITALIC MODERN; 17 and 23 BOURGEOIS; long primer ITALIAN, SKELETON ANTIQUE, and CONDENSED SANS NO. 5; brevier CONDENSED SANS ITALIC; long primer CONDENSED SANS and GOTHIC; 10-point HAWARDEN and WINCHELL; 8-point CONDENSED WINDSOR; long primer RONALDSON; PICA TYPEWRITER; 12- and 8-point BLACKFRIARS ROMAN; 10-point BLACKFRIARS ITALIC; 12-point COLUMBUS; 8-point MORLAND; 12-, 10-, and 8-point CHELTENHAM OLD-STYLE; 12-, 10-, and 8-point CHELTENHAM BOLD CONDENSED; 12-, 10-, 8-, and 6-point CHELTENHAM BOLD; 12-, 10-, and 8-point CHELTENHAM BOLD EXPANDED; 12-, 10-, and 8-point CHELTENHAM WIDE; 12-, 10-, 8-, and 6-point DE VINNE CONDENSED; 12-, 10-, 8-, and 6-point DE VINNE; and 12-, 10-, and 8-point DE VINNE ITALIC).

c. Type of materials other than type-metal (including steel, brass, and wooden letters).

d. INITIALS.

e. Type for illustrating games (including the following figures: 63---CHESS, 64---DRAUGHTS, 65---PLAYING-CARDS, 66---DICE, 67---DOMINOES, and 68---BACKGAMMON or trick-track showing small dice and counters).

f. ITALIC and SCRIPT (including figures 69 through 73---script type sections and body diagrams).

g. TYPEWRITER, DUPLICATING-MACHINE, and ADDRESSOGRAPH type (including figure 74---CHEQUERED FACE TYPEWRITER type, and figures 75 through 81 which show various type-bodies for machines).

h. Type for miscellaneous purposes, leads, and furniture (including the following figures: 82 and 83---SEMAPHORE; 84 and 85---MORSE; 86---WHEATSTONE perforated ribbon and MORSE tape; 87 and 88---embossing machine and GRAPHOTYPE; no figures for PRINTING-TELEGRAPH type and NUMBERING-MACHINE type; 89---MUSIC; 90---SHORTHAND; 91 and 92---BRAILLE; 93---REVERSED; 94---LOGOTYPE matrix-box; 95 through 109---BORDERS, CORNERS, COMBINATION BORDERS, ORNAMENTS, COMBINATION ORNAMENTS, GROUNDWORK, NATURAL OBJECTS, RULES and CHEQUE-RULES, SCROLLS, BRACES, ARROWS, ORNAMENTAL DASHES, PEN or LINE DASHES, FLOURISHES, COMBINATION FLOURISHES, COLOPHONS, and ILLUSIONAL FORMS; 110---lead-cutting machine; and 111 through 117---various types of furniture).

i. Accuracy of type faces (including figures 118---lock-up test for accuracy of type, and 119---exactitude of face reproductions).

9. Series, proportions, and weight.

a. Series (including series of type faces, family, line, figure 120---type series, table 10---amount of beard expressed in points, table 11---position of the standard line in GERMAN type in Didot points, and figure 121---point title line of letters).

b. Proportions (including tables 12 through 24, which show the bills of type for ENGLISH, WELSH, FRENCH, GERMAN, ITALIAN, SPANISH, BOHEMIAN, GREEK, RUSSIAN, and HEBREW).

c. Weight of type (including tables 25 and 26, which show weights, by sizes, of English and French types in quantities of 1,000,000).

10. Logotypes (sometimes called polygraphs or polygrams, and includes ligatures).

a. History and frequency (including figure 122---ligatures, and the following tables: 27---number of logotypes in 100,000 characters; 28---logotypes per 100,000 characters, roman lower-case, capitals, and points, a comparison; 29---logotypes per 100,000 characters, roman lower-case, capitals, and points, variation in frequency of occurrence; and 30---comparison of observed and calculated frequency of occurrence of individual characters per 100,000).

b. Possible reforms in or modification of the alphabet (including table 31---

sounds represented by two-letter combinations per 100,000 characters; and figure 123---a sample proposal, illustrated textually, wherein "th" and "ng" are combined into one symbol each).

11. Legibility.
    a. Factors affecting legibility (including size of the characters; amount of space between succeeding lines or the amount of leading; amount of white between the main strokes or in the counters; length of the printed line; resemblance of some characters to others; presence of unnecessary lines or marks, ornamental or otherwise; frequency of kerns in certain characters; quality of the paper and its colour; colour of the ink; capacity of the paper for reflecting light; illumination; and irradiation).
    b. Type, leading, and length of line for school-books (including size of type and leading; length of the printed line; recommendations of Dr. Cohn for type for school-books showing four samples; recommendations of the British Association Committee showing five samples; the influence upon the style of character arising from the manner in which payment is made to the compositor; and amount of white between the main-strokes and in the counters).
    c. Resemblances of some characters to others (including the following overlay figures and related tables, respectively: 124/32---illegibility of ROMAN MODERN (lower-case), 12-point letters c vs. e vs. o, f vs. f (long s), b vs. h, a vs. s, i vs. l, and n vs. u; 125/33---illegibility of ROMAN OLD-STYLE (lower-case), 12-point letters c vs. e vs. o, b vs. h, a vs. s, i vs. l, and n vs. u; 126/34---illegibility of ROMAN BLACKFRIARS (lower-case), 12-point letters c vs. e vs. o, b vs. h, a vs. s, i vs. l, and n vs. u; 127/35---illegibility of ROMAN SANS SERIF (lower-case), 12-point letters c vs. e vs. o, b vs. h, a vs. s, i vs. l, and n vs. u; 128/36---illegibility of German FRAKTUR (lower-case), 12-point letters c vs. e vs. o, b vs. h, f vs. f (long s), i vs. l, n vs. u, a vs. v, and m vs. w; 129/37---illegibility of MODERN, OLD-STYLE, BLACKFRIARS, and SANS SERIF 12-point figures 3 vs. 5 and 6 vs. 8; 130-133/38---illegibility of MODERN, OLD-STYLE, BLACKFRIARS, and SANS SERIF (capital) letters C vs. G, O vs. Q, B vs. R, X vs. Z, and (for SANS SERIF) F vs. P; 134/38---illegibility of FRAKTUR (capital) letters C vs. E, O vs. O, B vs V, and F vs. I; 135/38---illegibility of GREEK (capital) letters A vs. Λ, H vs. Π. O vs. Θ, and Δ vs. Λ (i.e. alpha vs. lambda, eta vs. pi, omicron vs. theta, and delta vs. lambda); 135/39---illegibility of GREEK (lower-case) letters ν vs. υ and ζ vs. ξ (i.e. nu vs. upsilon and zeta vs. xi); 136/39---illegibility of RUSSIAN (lower-case) letters П vs. Н, П vs. И, П vs. Ц, И vs. Ц, and Ш vs. Щ (i.e. pé vs. en, pé vs. ee, pé vs. tsé, en vs. tsé, and sha vs. shtcha): 137/39---illegibility of HEBREW letters ג vs. נ and ם vs. ס (i.e. gimel vs. nun and mem-final vs samech); 138/40---illegibility of DEVANAGARI characters अ vs. च, भ vs. म, म vs. न, घ vs. ध, ऊ vs. ज, and व vs. ब vs. ब्र (i.e. a vs. ch, bh:

vs. m, m vs. n, dh vs. gh, û vs. j, and v vs. b vs. br); 139/40---illegibility of ARABIC characters ﺑ vs. ﻧ , ﺒ vs. ﻴ , ز vs. ر vs. و , ﺍ vs. ﻟ , and ل vs. ن (i.e. initial b vs. n, medial b vs. y, normal z vs. r vs. w, initial a vs. l, and detached l vs. n); and figure 140---illegibility of FRENCH (lower-case) accents è vs. é vs. ê and c vs. ç, and points "." vs. ",").

d. Influence of parts of the character on legibility (including a chart of the number of lower-case and capital letters still legible after removal of one-half of the letter, and figure 141---comparison of legibility of upper and lower halves of type).
e. The line followed by the eye (including figure 142---mean resultant character obtained by combining in their proper proportions the whole of the lower-case characters and f-ligatures of an OLD-STYLE 12-point face, with the centre of gravity of the character marked by a white cross).
f. Operations involved in the process of reading (Cattell's experiments).
g. Illumination and reflection (including the quality of the paper, its colour, and the colour of the ink; reflection of light, and illumination; and irradiation as shown in figures 143 and 144, which produce illusions of size and tint, respectively).

12. Punch-cutting (history and techniques).
13. Matrices (history, types, and techniques).
14. Moulds (description, types, and techniques).
15. Pumps (history, and description of types).
16. The classification of typecasting machinery, composing machinery, justifying appliances and distributing appliances, and of machines which embody two or more of the operations or processes described.
17. Keyboards (including arrangement of cases, and descriptions of composing machines and distributing keyboards).

18-30. Casting; composing; line-justifying; distributing; casting/composing; casting/line-justifying; casting/distributing; composing/line-justifying; composing/distributing; casting/composing/line-justifying; composing/line-justifying/distributing; matrix-composing/line-justifying/type (or slug) casting; and impression, transfer, type-bar, photographic, and unclassified machines.

31. Stereotyping (processes and techniques).
32. Typographical etching, relief process blocks, and electrotyping.
    a. History and processes (including a description of colour-printing, terms associated with colour, the aesthetic effects of colour, and plate CIV---continuous spectrum reproduced by the three-colour process).
    b. Electrotyping.
33. The language of China and its typographical expression (history and description).
34. Hieroglyphic, cognate, syllabic, and other scripts.
35. Ancient and modern scripts and their uses.
    a. Alphabets and syllabaries (including the following samples: 10-point

MILISEET, 11-point NAMA or KHOI-KHOI, 11-point ANGLO-SAXON, 8-point INSCRIPTION ROMAN Numbers 3 and 4, 10-point MANUSCRIPT GREEK (Codex Vaticanus), 18-point MANUSCRIPT GREEK (Codex Alexandrinus), 10-point INSCRIPTION GREEK NO. 2, 12-point GERMAN FRAKTUR NO. 3, 8-point ANCIENT SLAVONIC (Bulgarian Glagolitic), 12-point BULGARIAN, 10-point ABKHAZIAN, 11-point RUNIC (Old Norse), 10-point GOTHIC, 11-point IRISH (Erse) or GAELIC, 14-point ECCLESIASTICAL GEORGIAN, 18-point CIVIL GEORGIAN, single and double alinement ARABIC, 24-point NESTORIAN (Syro-Chaldaic), 18-point ESTRANGELO (Syriac), 18-point PESHITO (Syriac), 12-point MODERN SYRIAC, 18-point CUFIC (Arabic), 24-point CARSHUNI, 11-point ARMENIAN NO. 1, 11-point ARMENIAN NO. 1 (Kurdish), 12-point RABBINICAL (Hebrew), 18-point ACCADIAN CUNEIFORM, 14-point ASSYRIAN CUNEIFORM, 12-point BABYLONIAN CUNEIFORM, 14-point PHOENICIAN, 12-point SAMARITAN, 12-point PALMYRENE, 18-point OUTLINE HIEROGLYPHIC (Egyptian), 18-point HIERATIC (Egyptian), 12-point DEMOTIC (Egyptian), 12-point COPTIC NO. 2 (Bohairic or Northern), 12-point COPTIC NO. 3 (Sa'idic or Southern), 14-point ZEND, 11-point AMHARIC NO. 2, 12-point ETHIOPIC NO. 1, 16-point HINDI NO. 3 (Devanagari), 12-point BENGALI NO. 2, 12-point PANJABI (or Sikh) NO. 8 (Gurumukhi), 18-point THAKURI (Chamba), 14-point GUJARATI (Guzerati), 14-point KANARESE NO. 1, 14-point TELUGU NO. 1, 12-point TAMIL NO. 2, 14-point MALAYALIM, 14-point ORIYA (Uriya), 11-point SINHALESE (Cingalese), 22-point LEPCHA, 18-point TIBETAN, 18-point BURMESE, 18-point SIAMESE, 24-point LAO-TIAN (Lao-shan), 14-point KANA-MAJIRI (Japanese), 14-point KATA-KANA (Japanese), 14-point HIRA-GANA (Japanese), 14-point KOREAN, 18-point KALMUK, 18-point MANCHU, 18-point MONGOLIAN, 22-point JAVANESE (Sundanese), 10-point BATTA, 14-point BUGI, 18-point BISAYA (Visaya), 10-point CHEROKEE, 14-point CHIPPEWYAN, and 14-point ESKIMO (Innuit)).

b. Specially devised alphabets and syllabaries (including samples of the following: 11-point COMPASS (or CV), showing also the relationship of characters in its alphabet; and 18-point UNIVERSAL SYLLABICS).

c. Music composition (including samples of diamond MUSIC, bourgeois PLAIN-SONG, and brevier (or tonic) SOL-FA).

36. Conclusion.

Appendix I: Bibliography.

Appendix II: British and American patents relating to the preparation of the typographical printing-surface, together with a brief note on each patent (British---2923, American---3873, total---6796).

Appendix III: Technical vocabulary; tri-lingual in English, French, and German (including 709 nomenclature, 55 character-type, and 82 language-name terms).

Appendix IV: Note on standardization of nomenclature.

Appendix V: List of (609) illustrations.

Index.

It is especially noted that the illustrations in this encyclopedic work are almost encyclopedic themselves. Of particular interest are the illustrations of (1) illegibility (chapter 11), which are shown superimposed one on another, and (2) Chinese, Hieroglyphic, cognate, syllabic, and other ancient and modern, general- and special-purpose scripts (chapters 33-35).

* * *

2553 Lippert-1962

Lippert, S.
Douglas Aircraft Co., Inc., El Segundo, Calif.
DYNAMIC VISION--THE LEGIBILITY OF EQUALLY
SPACED ALPHA-NUMERIC SYMBOLS
Rept. no. LB 30961, 12 Jul 62, 35 p., 5 refs.
Contract Nonr 1076(00)
AD-285 817
Also in Human Factors, 5:2 (April 1963) 129-138

Problem: Determine the effect of stimulus motion on the legibility of black on white, alpha-numeric characters, such characters being a simulation of the motion of "targets" when being viewed from a moving vehicle, such as an airplane or an automobile.

Procedure: Six male/female subjects* (having monocular visual acuity of 18/20 or better) viewed 42-point type (TYPE MASTER VC-V4271, printed on a Coxhead-Liner Composing Machine using the ALTERNATE GOTHIC, STYLE 71 template) black on white (in a purple-gray cast caused by a two-way mirror), alpha-numeric characters, vertically arrayed on a moving (top to bottom) endless-belt display at a distance of 38 $\pm$ 2 inches. The character height of 7/16 inches provided a visual angle of 39 minutes. Stroke-width of the characters was 1/16 inches. The vertical space between characters subtended 51 minutes. Average contrast of the stimulus surface, as viewed by the subject, was 93 percent at approximately 3 foot-lamberts. An auditory background masking noise (simulating the cockpit noise in an airplane) was provided. Speed of the moving belt was varied between threshold (the point at which a subject could recognize one character) and 100 percent. At various belt speeds, masks were placed over the stimuli that provided reading areas 2 inches wide and 2, 8, or 20 inches high. Performance criteria was the number of correct identifications per angular velocity of the stimuli. It was noted that some of the subjects utilized saccadic eye movements to "stop" the display. These included judiciously timed blinking and self-induced nystagmus. Head movements were also noted.

Result: Experimental results were as follows:

1. Mean angular velocity for zero legibility varied from 30 degrees per second for the 2-inch aperture to 56 degrees per second for the 20-inch aperture. For 100 percent legibility, the mean angular velocity varied from 10 degrees per second for the 2-inch aperture to 16 degrees per second for the 20-inch (zero : 100% $\cong$ 3 : 1 angular velocity).
2. Since the letter "M" seemed to enjoy the highest legibility, it was used in the threshold trials. Other characters that appeared to have high legibility were 8, E, A, S, 3, and X.
3. It is difficult to judge the effect of the eye and head movements on the experimental results (except that some movements could raise the angular velocity at threshold by essentially simulating a tachistoscopic display) since eye and head movements

are both permitted in the real-life situation.

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* While five of the subjects were "naive," one was not only a former pilot, but also a member of the human factors group.

* * *

3304 Long-1951

Long, E. R., Reid, L. S. and Queal, R. W.

Virginia U., Charlottesville

FACTORS DETERMINING THE LEGIBILITY OF LETTERS AND WORDS DERIVED FROM ELEMENTAL PRINTERS

Third report on the "Infomax" principle (for 1 and 2, see Long-1952a and b, following)

AF Technical rept. no. 5924, Aug 51, 33p., 3 refs.

Contract W-33-038 ac-21269

ATI-184 797

Problem: In determining the legibility of letter and word patterns formed by elements or "dots," as output from a pulse-activated elemental printer, consider the effect of number, size, and gray scale of elements vs. each other and vs. the type and degree of degradation, on letters, words, and letter-group "jumbles."

Procedure: This was the last of a series of three experiments and differed from the two previous investigations by the following factors:

1. Letters were presented not only singly, but in groups of four letter actual and jumbled words.
2. Many more subjects were utilized, each of whom viewed only a specific group of 33, rather than all of the 1584 stimuli.
3. Only 11 of the possible 26 alphabetic characters were utilized for recognition purposes.

Thus, "144 subjects were randomly distributed among the 48 different combinations of matrix size, degradation type, degree of degradation, and printed brightness. Further, the three subjects assigned to a given combination were to view only the 33 slides (11 single letters, 11 meaningful words, and 11 random four-letter groups) of that particular combination and no others." (p. 2) Subjects viewed presentations of dark on white, experimental, upper case, alphabetic patterns (approximating the Control Instrument Company's alphabetic element set) for 4 seconds each (with 6 seconds between exposures) at a constant viewing brightness of 87.5 millilamberts, and a viewing distance of 14 inches. Letters were 3/8 inch high, 1/4 inch wide, and had a stroke-width of 1/16 inch, providing visual angles of 1 degree and 30 seconds, 1 degree, and 20 minutes, respectively. The experimental design was a factorial of the following variables:

1. 35 and 140 matrix elements, with the latter elements each covering 1/4 the area of one of the "35 matrix" elements,

2a. addition of supurious (randomly inserted) active elements (falling in the non-figure areas), omission (again random) of signal elements (in figure areas), and a

combination of both,

2b. addition of spurious (randomly inserted) active elements (falling in the non-figure areas and randomly "printed in either black, dark gray, (or) light gray but never white") (p. 4), omission (again random) of signal elements (in figure areas and randomly "printed in either white, light gray, or dark gray but never black") (p. 4), and a combination of both,

3. 0, 10, 30, and 60 percent (of active figure elements, to the nearest round number) degrees of the six above types of figure degradation, and

4. letters presented singly (A, B, E, K, O, P, R, S, W, X, and Z were randomly selected from the total 26), in arbitrarily selected words (YARD, BEAN, MOVE, JOKE, HOCK, SLIP, TURF, STAG, WISH, EXAM, and QUIZ), and in random, four letter anagrams of the above words (RYDA, NBEA, MEOV, JKEO, OCHK, LPSI, UFTR, GSAT, HWSI, MEXA, and IUQZ). The shape of letter elements (unlike the CIC set, these elements were square and abutted each other), letter stroke-width, and letter styles were held constant. Identification accuracy was the test criterion.

Result: "The same factors as in the previous studies were found to decrease legibility. Again legibility loss was minimized, by the use of a larger matrix and by printing in the gray scale. Four-letter words and single letters were equally legible (or illegible); four-letter jumbles were less legible under all experimental conditions. The less highly trained observers in this study demonstrated consistently lower and more variable performance than those of the earlier studies, using the same stimulus patterns." (p. iii) The results (with possibly some implications for the engineering design of element printers) specifically indicated the following:

1. "(I)f coded text is to be used, it should involve the presentation of individual letters or sequences of letters which have 'meaning' for the operator." (p. 29) In connection with this there is discussion on the possible role of "learning" in the recognition situation with the conclusion that ". . . efficiency of a presentation device is a function of . . . (operator) training . . ." (p. 32)
2. Loss of recognition decreased maximally when the number of elements was increased, if omission or addition only were present, and less than maximally when there was a combination of both. "(P)erhaps for some letters the use of gray scale produces better recognition, while for others increasing number of matrix elements is superior. This line of reasoning is based on . . . letters depend(ing) for their correct recognition upon certain 'critical portions'." (p. 29-30) Gray scale plus increased matrix size gave greatest recognition improvement, especially when omission and addition were both present.
3. The disproportionality of omission plus addition vs. either omission or addition alone, as seen in previous experimentation, is discussed further, particularly for the cases in which the disproportionality disappears. Despite these reversals, it is still suggested that the system be either highly sensitive or highly insensitive.

Further the system should be designed to provide minimal degradation of the stimulus pattern, and in this, to print signal and noise in differential brightness according to their intensities.

Further research should center around (1) factors determining legibility of numbers, (2) "the variable of type of print" (p. 32) (i.e. design, case, etc.), (3) signal to background contrast and color, (4) verification of results in these experiments "in light of equipment specifications," (p. 32) and (5) the dependence of "pattern intelligibility (on) operator familiarity with the stimulus vocabulary and practice level of viewing." (p. 32)

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2173 Long-1952a

Long, E. R. and Reid, L. S.

Virginia U., Charlottesville

FACTORS DETERMINING THE LEGIBILITY OF LETTERS AND WORDS, PRINTED IN "DOT" PATTERNS WITH PURE BLACK AND WHITE WHEN THE PATTERNS ARE DEGRADED IN VARYING AMOUNTS

First report on the "Infomax" principle

AF technical rept. no. 5922, Apr 52, 23 p., 1 ref.

Contract W33(038) ac-21269, Proj. 7192

AD-1 144

Problem: In determining the legibility of letter patterns formed by elements or "dots," as output from a pulse-activated elemental printer, consider the effect of number and size of elements, type and degree of degradation, and viewing brightness.

Procedure: Four subjects (who were informed as to the nature of the experiment) each viewed 1040 stimulus presentations of single, black-on-white, experimental, upper case, alphabetic patterns (approximating the CONTROL INSTRUMENT COMPANY's alphabetic element set) projected on a milk-glass screen, for 4 seconds each (with 6 seconds between exposures), at a viewing distance of 14 inches. Letters were 3/8-inch high, 1/4-inch wide, and had a stroke-width of 1/16 inch, providing visual angles of 1 degree and 30 seconds, 1 degree, and 20 minutes, respectively. The experimental design was a factorial of the following variables:

1. 35 and 140 MATRIX elements, with the latter elements each covering 1/4 the area of one of the 35 MATRIX elements,
2. addition of spurious (randomly inserted) active elements (falling in the non-figure areas), (random) omission of signal elements (in figure areas), and a combination of both,
3. 0, 10, 30, and 60 percent (of active figure elements, to the nearest round number) degrees of the three above types of figure degradation, and
4. 6.5 and 87.5 millilambert viewing brightnesses (with a constant 87.5 millilamberts between exposures).

All 26 alphabetic characters were used. The size (sic) and shape (unlike the CIC set, these were square and abutted each other) of elements, the stroke-width, and the letter styles were held constant. Identification accuracy was the test criterion.

Result: Generally, "legibility was found to depend upon all of the variables except viewing brightness. Statistically significant differences were also found among the subjects." (p. iii) Specifically, the following results were shown:

1. "Numbers of correct recognition of elemental formed letters are reduced by all types of degradation--omission of figure (signal) elements, addition of spuriously active non-figure (non-signal) elements, and equal amounts of simultaneously combined omission and addition, these reductions being dependent upon the degree of degradation.
2. "The reduction in correct recognitions is dependent upon the degree of degradation, greatest reductions being produced by greatest degrees of degradation.
3. "Reductions in recognition produced by the various types and degrees of degradation may themselves be lessened by increasing the number of elements of equal area matrices. These increases in numbers of correct recognitions produced by increases in number of matrix elements appear to be most pronounced at the greater degrees of degradation (30 and 60 percent).
4. "There are statistically significant differences among subjects which appear to be independent from any of the manipulated variables.
5. "Increasing viewing brightness from 6.5 to 87.5 millilamberts does not significantly alter numbers of correct recognitions." (p. 22)

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2172 Long-1952b

Long, E. R. and Reid, L. S.
Virginia U., Charlottesville
FACTORS DETERMINING THE LEGIBILITY OF LETTERS AND WORDS PRINTED IN "DOT" PATTERNS WITH DIFFERENTIAL BRIGHTNESSES OF THE PATTERNS PROPORTIONAL TO THE AMOUNT OF DEGRADATION
Second report on the "Infomax" principle
AF technical rept. no. 5923, Apr 52, 25 p., 2 refs.
Contract W33(038) ac-21269, Proj. 7192
AD-1 145

Problem: In determining the legibility of letter patterns formed by elements or "dots," as output from a pulse-activated elemental printer, consider the effect of number, size, and gray scale of elements vs. each other and vs. the type and degree of degradation.

Procedure: This experiment differed from the previous investigation (Long-1952a) by the following two factors:

1. Brightness of viewing, which had two values (6.5 and 87.5 millilamberts) in the first experiment, was held constant at 87.5 millilamberts.
2. A gray scale was introduced to produce (in addition to white and black) a light and dark gray. This was done on the basis of work at the Hogan Laboratories "which allows signal and noise to be printed in brightnesses proportional to their respective strengths." (p. 1)

Four subjects each viewed 2080 presentations (2 each of 1040 stimuli) of single, dark on white, experimental, upper case, alphabetic patterns (approximating the CONTROL INSTRUMENT COMPANY's alphabetic element set) for 4 seconds each (with 6 seconds between exposures), at a constant brightness of 87.5 millilamberts and a viewing distance of 14 inches. Letters were 3/8-inch high, 1/4-inch wide, and had a stroke-width of 1/16 inch, providing visual angles of 1 degree and 30 seconds, 1 degree, and 20 minutes, respectively. The experimental design was a factorial of the following variables:

1. 35 and 140 MATRIX elements, with the latter elements each covering 1/4 the area of one of the 35 MATRIX elements,
2. addition of spurious (randomly inserted) active elements (falling in the non-figure areas and randomly "printed in either black, dark gray, (or) light gray but never white") (p. 4), omission (again random) of signal elements (in figure areas and randomly "printed in either white, light gray, or dark gray but never black") (p. 4), and a combination of both, and
3. 0, 10, 30, and 60 percent (of active figure elements, to the nearest round number) degrees of the three above types of figure degradation.

All 26 alphabetic characters were used. The size (sic) and shape (unlike the CIC set, these were square and abutted each other) of elements, the stroke-width, and the letter styles were held constant. Identification accuracy was the test criterion.

Result: "The following are tentative findings: (1) Stimulus legibility was again found to be reduced by all types of degradation (element omission, addition, and simultaneous addition plus omission). (2) Loss of intelligibility may be reduced either by increasing the number of matrix elements (from 35 to 140), or by changing from letters printed in pure black and white to those utilizing the gray scale. (3) Statistical analysis of the data indicates that simultaneously combined addition of spurious elements and omission of signal elements reduces stimulus legibility disproportionately more than does either addition or omission alone." (p. iii) A comparison of the results here with those of the first experiment indicated that "unless the communication system is designed to employ both the 140-ELEMENT MATRIX and the gray scale, it might be well to design the system so that it will be either highly sensitive or highly insensitive (giving) . . . either much addition but with no omission or much omission with no addition." (p. 22-23) This is based on "the assumption . . . that either of these will reduce recognitions less than will a simultaneous combination of equal amounts of each . . ." (p. 23)

* * *

3305 Long-1954

Long, E. R., Reid, L. S. and Garvey, W. D.

Virginia U., Charlottesville

THE ROLE OF STIMULUS AMBIGUITY AND DEGREE OF RESPONSE RESTRICTION IN THE RECOGNITION OF DISTORTED LETTER PATTERNS

Fourth report on "Set" as a determiner of perceptual responses

WADC Technical rept. 54147, May 54, 18p., 4 refs.

Contract W33-038 ac-21269

AD-48 906

Problem: "(E)xplore the basic operation of perceptual 'set' as response restriction . . . (through the) identif(ication of) single distorted letters." (p. iii) Results should "furnish answers to the following questions:

1. "Can identification response uncertainty be reduced by figural cuing alone, i.e., when independent from areal cuing?
2. "Are the identification-response restriction effects of figural cuing operations dependent upon the level of figural contour distortion and thus level of identification response uncertainty?
3. "Do the setting effects of figural cuing influence the stimulus-identifying response class directly or by limiting some other earlier response class in the chain, e.g., detection or location, which in turn sets the occasion for a correct identifying response?" (p. 3)

Procedure: Thus, "three variables---level of uncertainty, degree of response limitation, and temporal position of cuing were organized into a . . . factorial design" (p.4) experiment. In it, 108 male subjects (college students) viewed degraded, single-letter (11 of 26 from the "infomax" studies), ELEMENT MATRIX style, black-on-white, upper case, alphabetic characters projected on a screen and "subtending visual angles ranging from 3.5$^{\circ}$ to 6$^{\circ}$." (p. 4) Level of uncertainty was varied by providing letters for which varying degrees of recognition difficulty had been previously ascertained without cuing. Percentages of correct recognition for the three difficulty levels had been 55 percent, 22 percent, and 4 percent. Degree of response limitation was varied by providing the subject with "small sheets of paper on which were printed either 4, 6, 8, or 11 letters, one of which corresponded to the stimulus letter . . ." (p. 6) Temporal position of cuing was varied by providing the subject with one of the above "cuing sheets" either before and after, only before, or only after, the stimulus presentation. The cuing sheet also served as an answer sheet. Accuracy was the test criterion.

Result: "(R)esults showed that cuing or response-restricting information greatly increased the number of correct identifications for the various conditions of the experiment, thus confirming the hypothesis as to the beneficial effects of response restriction for the

identification of ambiguous letter stimuli. Both level of response uncertainty and degree of response restriction significantly influenced the number of correct letter identifications. The effects of the setting operations employed in this experiment were, however, independent from the degree of response uncertainty or stimulus distortion. Pre-stimulus cuing was significantly poorer than either post-stimulus or pre- plus post-stimulus cuing. This finding . . . indicat(es) that identification responses are best restricted by post-stimulus cuing." (p. 17)

* * *

2176 Long-1955

Long, E.R. and Garvey, W.D.
Virginia U., Charlottesville
THE ROLE OF SETTING CUES IN REDUCING THE SIMULTANEOUS LOCATION AND IDENTIFICATION AMBIGUITY OF LETTER PATTERNS
Fifth report on "Set" as a determiner of perceptual responses
WADC technical rept. 54-289, Apr 55, 19 p., 6 refs.
Contract W33(038) ac-21269, Proj. 7192
AD-85 564

Problem: "Practical situations involving data presentation frequently require the operator to search for and select a critical stimulus before attempting to identify it. It was therefore sought to learn how setting cues might be utilized to facilitate identification when both location and identification uncertainty existed simultaneously in the ambiguous stimulus situation." (p. iii) Specifically, the study sought "answers to the following . . . questions: (1) When location or search response uncertainty is simultaneously present with identification response uncertainty, will locational cuing, added to identification cuing, increase correct identifications of distorted figures? (2) Is the obtained setting effect related to the degree of figural contour distortion? (3) Will pre-stimulus figural (identification) cuing combine with locational cuing to produce more correct identifications than will post-stimulus figural cuing? (4) If such evidence is found, will this facilitation of identification be a function of the degree of locational cuing and the level of figural contour distortion?" (p. 17)

Procedure: "Multiple distorted letters of the alphabet were employed to provide (the above) condition, (72 male, student) subjects being required to select and identify a single critical letter (from slides containing four distorted letters previously developed for the INFOMAX studies). Principal experimental variables were degree of location restriction and level of figural contour distortion. Degree of identification restriction was held constant. . . (p. iii) The final stimuli were presented by projecting . . . transparencies on a screen. . . The projected . . . letter patterns subtend(ed) visual angles ranging from 3.5 . . . to 6.0 (degrees). . . (p. 6) Temporal position of figural cuing was manipulated by having one-half of the subjects view four undistorted letter alternatives both before and after stimulus presentation, while the other half . . . viewed these cuing letters only after stimulus presentation." (p. 17)

Result (fifth of the series): "Locational setting cues were found to aid identification, but only when so specific as to reduce location uncertainty to zero. This setting effect was independent from the level of figural distortion, although the latter variable itself significantly influenced identification. . . (p. iii) Temporal position of figural cuing did not significantly influence identification, pre- plus post-stimulus cuing being no better than post-stimulus cuing alone. In addition this variable did not interact significantly with either level of stimulus difficulty or degree of location restriction." (p. 18)

Result (entire series): "This program of experiments has yielded a number of generalizations which presumably have application to several practical aspects of the presentation and reception of information. The more definite of the generalizations are the following:

1. "Cuing information given to the subject relative to ambiguous stimuli can materially reduce perceptual errors. This finding holds for both the location of critical stimuli made difficult by the presence of irrelevant clutter, and the correct identification of stimuli with distorted contours.
2. "The facilitating effect of the setting cues is dependent upon the degree of response restriction achieved by the setting information.
3. "The helpful effect of setting the observer depends upon the degree of stimulus ambiguity, setting being more beneficial as response uncertainty increases. This interaction is more significant at the extremes of stimulus ambiguity than in the middle range.
4. "In order to facilitate the location or selection of critical stimuli, presented with background 'clutter', the setting cues must be given to the observer prior to presentation of the stimulus field.
5. "Where setting cues are utilized to aid the identification of ambiguous stimuli, the cuing may be done either before or after stimulus presentation. Post-stimulus setting appears to be as effective, or more so, than pre-stimulus cueing for this purpose." (p. 15)

"This last finding, which had not been entirely anticipated, probably warrants some discussion . . .. Fundamentally, the facilitating effect of post-stimulus setting cues indicates that if the number of final instrumental responses to be made by the operator is decreased, the informational carrying capacity of the same degraded message signal will be increased. . . Whereas it may be operationally impractical to reduce the number of responses under most conditions, it should be quite feasible for special situations (such as unusual flight missions) to cut down stringently the number of response alternatives in order to save communication or to insure a maximum probability of correct operator response. The evidence afforded by the post-message cuing in the present experiments with regard to the value of such a response-limiting procedure is of considerable relevance here." (p. 16)

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2181 Longyear-1936

Longyear, William

A DICTIONARY OF MODERN TYPE FACES AND LETTERING

Pelham, N. Y., Bridgman Publishers, Inc., 1936,

Third edition, 122 p.

Problem: Prepare a manual of printing and lettering typefaces, showing each face in several sizes and both cases together with numerals. Utility of the manual should be to both advertising layout and new-book typography.

Procedure: "Type history is divided into five periods as follows---

| | | |
|---|---|---|
| Venetian, 16th century, | typified by CLOISTER | (embellished) |
| Old Style, 17th century, | typified by CASLON | (serif) |
| Transitional, 18th century, | typified by BULMER | (serif) |
| Modern, | typified by BODONI | (serif) |
| Contemporary, present day, | typified by FUTURA." | (sans serif) |

The following "facts concerning printing" are shown:

1. "Type is generally classed as follows:"
   a. roman and italics
   b. upper- and lower-case
   c. light, medium, and bold
2. "The printing surface of type is called the face."
3. "The design of the face gives the type its name . . . ."
4. "The size of type relates to the body."
5. "The following point system of measuring type is in general use:
   a. 6 points = 1 nonpareil
   b. 12 points = 2 nonpareil or 1 pica
   c. 6 picas = 1 inch
   d. 72 points = 1 inch."

Proofreader's marks and Monotype Rules are also shown.

Result: The following type- and lettering-faces are shown:

ASTREE (roman and italic)
BARNUM
BERNHARD (roman and italic)
- CURSIVE (medium and bold)
- FASHION
- FINE
BETON (medium, bold, and extra bold)
- OPEN
BODONI (light, medium, and bold)
- (italic: medium and bold)
- BOOK (roman and italic)
- SHADED
- ULTRA (roman and italic)
- ULTRA (condensed and extra condensed)

BOOKMAN
BRUCE EXTRA BOLD (roman and italic)
BRUSH SCRIPT
BULMER (roman and italic)
CASLON
- 540 (roman and italic)
- AMERICAN (roman and italic)
- BOLD (roman and italic)
- BOLD CONDENSED
- HEAVY
- MODERN
- NEW
- OPEN FACE
- RECUT ITALIC
CAXTON
CENTURY EXPANDED
- FIGURES
CHARTER OAK
CHELTENHAM (roman and italic)
- BOLD (roman and italic)
- CONDENSED (bold and extra bold)
- OLDSTYLE
CLOISTER (roman and italic)
- BLACK
- BOLD
COCHIN-NICHOLAS ITALIC
COLWELL ITALIC
COOPER (roman and italic)
- BLACK (regular and condensed)
CORVINUS (light: roman and italic, medium: roman and italic, and bold)
DELLA ROBBIA
DELPHIN
ENGRAVERS ROMAN
ERBAR (light and bold)
EVE (roman and italic)
- BOLD ITALIC
- HEAVY
FUTURA (light, medium: roman and oblique, demibold, and bold: roman and italic)
- BLACK
- DISPLAY
GALLEA
GARAMOND (medium: roman and italic, and bold: roman and italic)
GIRDER HEAVY
GLORIA
GOTHIC
- ALTERNATE
- CLEARFACE
- COPPERPLATE 1, 2, 3, and 4
- COPPERPLATE CONDENSED
- COPPERPLATE LIGHT
- FRANKLIN (roman and italic)
- FRANKLIN (extra and condensed)
- GILLES BOLD
- LIGHTLINE CAPS
- NEWS (condensed and extra condensed)
- PUBLICITY
GOUDY (light, medium italic, bold: roman and italic, and extra bold)
- CATALOGUE
- HAND TOOLED
GRECO ADORNADO
- BOLD
HANCOCK
HOBO
HOMEWOOD
Initials
- CALIGRAPH
- CINCINNATTI
- CLEARCUT
- CLOISTER

- DUTCH
- MISSALL
- VANITY
- VERSATILE
- VOGUE
- WEISS

JENSEN (roman and italic)

KABEL (light: roman and italic, medium, and bold: roman and italic)

KARNAK (light and bold)

LIBERTY

LUCIAN OPEN FACE

MANDATE

MAYFAIR

METROPOLIS (light and bold)

Miscellaneous

- BINNEY
- BOLD FACE NO. 1
- BRUCE O. S.
- MODERN EXTENDED

MODERN (roman: regular and condensed, and italic no. 8)

MODERNIQUE

Monotype faces included throughout list

NEULAND

- INLINE

NUBIAN

OLD STYLE (roman and italic)

ORPLID

PABST (roman and italic)

PARISIAN

PARSONS (light and bold)

POST

PRISMA

RALEIGH CURSIVE

ROMANY

ROUND HAND

ROYCROFT

SCOTCH (roman and italic)

- MONO

SHAKESPEARE

SIGNAL (light and medium)

SPHINX

STYMIE (light, medium, and bold italic)

SWASHES

TOWER

TRAFTON SCRIPT

TYPE UPRIGHT BOLD

TYPEWRITER

- REMINGTON

TYPO ROMAN SHADED

UMBA

WEBB INLINE

WEISS ITALIC

ZEPPELIN

* * *

2179 Loucks-1944a
Loucks, Roger B.
AAF School of Aviation Medicine, Randolph Field, Tex.
LEGIBILITY OF AIRCRAFT INSTRUMENT DIALS: THE
RELATIVE LEGIBILITY OF TACHOMETER DIALS
Rept. no. 1, Proj. 265, 30 May 44, 12 p.
AD-38 561

Problem: "(O)btain objective data that will provide specifications for optimum legibility of aircraft tachometer dials." (p. i)

Procedure: "Various modifications of the Type E-10 tachometer dial (were experimentally) compared as to the accuracy with which they can be read during brief (1.5 and .75 second) exposures." (p. i)

Result: "The data are consistent in demonstrating that the dial without subdivisions gives rise to fewer errors than dials with one or four subdivision lines. The data also indicate that the small numbers of the . . . E-10 . . . do not improve the accuracy with which this dial can be read. Where differences do arise, the dial with the small numbers tends to be in(f)erior to the more simple dials. . . (p. i) It is recognized that the dial which gives the fewest errors for brief exposure readings is not necessarily the one which will make possible the most precise readings were the subject to have unlimited time. There are very few aircraft instruments, however, which must be read with great precision." (p. 1)

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2177 Loucks-1944b
Loucks, Roger B.
AAF School of Aviation Medicine, Randolph Field, Tex.
LEGIBILITY OF AIRCRAFT INSTRUMENT DIALS: A FURTHER
INVESTIGATION OF THE RELATIVE LEGIBILITY OF TACHOMETER DIALS
Rept. no. 2, Proj. 265, 27 Oct 44, 6 p.
AD-132 973

Problem: "(O)btain objective data that will provide specifications for optimum legibility of aircraft tachometer dials." (p. i)

Procedure: "In the present study, tachometer dials have been constructed . . . which make it possible to investigate the influence on relative legibility of certain variations in the size (1/8-, 3/16-, and 9/32-inch height) and thickness (1/64-, 1/32-, and 3/64-inch stroke width) of division numerals. . . (Twenty s)ubjects were required to read the tachometer settings to the nearest 10 .". . (p. 2) revolutions per minute on the basis of a .75- or 1.5-second exposure under either incandescent or ultraviolet light. Numerals, marks and pointers were painted with fluorescent paint.

Result: "A tachometer dial which has division figures 3/16ths of an inch by 1/32nd of an inch proves, in general, to be as legible as dials with much thicker and larger numbers. This finding requires some qualification in that the large figures apparently caused some difficulty because their overall width made it difficult to select the particular division mark with which each number was associated. Had it been possible to construct dials with a different style of number in which the ratio of the height to the overall width was greater, the larger figures might conceivably have been superior. It should also be noted that such differences in legibility as were found to exist with ultraviolet light cannot be assumed to apply to a situation where the level of illumination permits an optimal degree of dark adaptation." (p. i) Finally, it is noted that orange fluorescent paint, which was not

available at the time of the experiments, may be superior to the yellow-green type used.

* * *

2180 Loucks-1944c

Loucks, Roger B.
AAF School of Aviation Medicine, Randolph Field, Tex.
LEGIBILITY OF AIRCRAFT INSTRUMENT DIALS: THE RELATIVE LEGIBILITY OF VARIOUS CLIMB INDICATOR DIALS AND POINTERS
Rept. no. 1, Proj. 286, 25 Nov 44, 10 p.
AD-132 977

Problem: "(O)btain objective data that will provide specifications for optimum legibility of climb indicator assemblies." (p. i)

Procedure: "Various modifications of the AC Type C-2 climb indicator have been compared as to the accuracy with which they can be read during brief exposures." (p. i)

Result: "Removal of all mid-division lines beyond the 500 (foot) point as well as the words 'up' and 'down' results in a dial which is more legible than the standard indicator. . . (Also,) mid-division lines which change in value from one part of a scale to another . . . give rise to errors. Although a majority of subjects being tested prefer(red) the dial with numbers at each of the scale divisions, the numerals at the 3, 000 (foot) and 5, 000 (foot) points of the simplified dial . . . can be omitted without decreasing its legibility. . . Under the specific conditions of this experiment, numbers and division lines 1/32 inch in thickness are as legible as heavier lines and numbers, and are superior to lines and numbers 1/64 inch in thickness. . . A pointer which has only a luminous tip is inferior in legibility to the standard dial hand, but a pointer with a strip of luminous paint only 1/32 inch in width, throughout its length, is as satisfactory as the standard hand." (p. i)

* * *

2178 Loucks-1944d

Loucks, Roger B.
AAF School of Aviation Medicine, Randolph Field, Tex.
LEGIBILITY OF AIRCRAFT INSTRUMENT DIALS: THE RELATIVE LEGIBILITY OF MANIFOLD PRESSURE INDICATOR DIALS
Rept. no. 1, Proj. 325, 7 Dec 44, 8 p.
AD-38 562

Problem: "(O)btain objective data that will provide specifications for optimum legibility of aircraft manifold pressure dials." (p. i)

Procedure: The experimental procedure was the same used previously (Loucks-1944a, Loucks-1944b, and Loucks-1944c).

Result: "With ultraviolet light the standard manifold pressure indicator dial (AC Type D-10) exhibits an improved legibility when the small numbers at the mid-division marks are obscured. . . A manifold pressure dial with 1/4 inch numbers is superior to a dial with 3/16 inch figures. It appears desirable to compress the width of the numerals in relation to their height in order that the association between a particular number and its appropriate division mark is of optimal clarity. . . It has been demonstrated that the starting point of a scale can be shifted considerably without affecting the dial's legibility. . . Within certain limits, the legibility of a dial appears to be closely associated with the angular spacing of the division marks. Two scales which have a difference in the angular

spacing of the division marks that is only about one and a half degrees exhibit a statistically significant difference. . . (p. i) (In general, ) once the dial scale has reached a certain degree of expansion, further simplification does not appear to affect its legibility." (p. 4)

* * *

2183 Luckiesh - 1923

Luckiesh, Matthew

LIGHT AND COLOR IN ADVERTISING AND MERCHANDISING

New York, D. Van Nostrand, 1923, 268 p.

Problem: Show the utility of light and color as advertising and sales media, including their effects on the legibility of printed and electrical display materials.

Procedure: This book, whose outline of contents follows, is almost purely textual in content, without benefit of many objective experimental results or much reference to other authorities. Included, however, are 37 plates, mostly in color, to illustrate various points.



Chapter XIV (electrical advertising) is more concerned with the topic of legibility than the others, with the single reservation that "the use of color (and illumination) is based upon the same general principles; therefore, the material of the early chapters is directly applicable . . . ." (p. 246)

Result: The following points are made concerning the legibility of poster boards and painted signs:

1. "The printed message on the sign-board must be reduced to a minimum of words . . . (with) (h)igh concentration on a single idea . . . ." (p. 246)
2. "(I)n magazine advertisements . . . it is easy to achieve legibility . . . by . . . (h)olding . . . copy or the printer's proof at arm's length (to) reveal its degree of legibility." (p. 247)
3. "The white spaces between black letters should be at least as wide as the black letters and preferably larger." (p. 247)
4. "Many sign-boards fail to deliver their message effectively because the lettering is too decorative, the contrast is too small, or the letters are not large enough." (p. 247-248)
5. "A large factor of safety should be allowed in order to insure legibility on dark days, in bad weather, and to allow for the speed of traffic." (p. 248)
6. "Color contrasts on sign-boards should be striking. Vivid colors are quite justifiable outdoors. However, in obtaining color-contrast it is a safety measure to achieve also a brightness-contrast." (p. 248) Dangers in brightness-contrast occur when color-vision fails (e.g. at twilight) and is found particularly with the color combinations red/green, orange/light-green, green/purple, yellow/gray, and any color with gray of the same brightness.
7. "Owing to certain complexities of vision, letters of certain colors are seen more clearly than others, assuming brightness-contrast to be the same in all cases. It is easier to focus red, orange, yellow at a distance than green, blue, or violet. Furthermore . . . the phenomenon termed irradiation (which makes an entity appear larger when bright than when dark) . . . complicates the legibility of bright painted letters and is a very important factor in electric signs where the letters and other portions of the sign are very bright." (p. 249)
8. Previous experimentation has shown the rank of "legibility of various combinations of colors in advertisements for reading at a considerable distance" (p. 250) to be in the following order: black, green, red, and blue on white; white on blue; black on white; yellow on black; white on red, green, and black; red on yellow; green on red; and red on green.

The following statements were made concerning primarily the legibility of electrically lighted signs:

1. The development of illuminated sign-boards (static and dynamic, continuous and flashing) has made progress primarily because the use of light commands attention, particularly at night. In this way, they are used for the purposes of designating a location and broadcasting a message. Legibility is concerned with both but particularly with the latter. In their development, the first signs (flat, painted, and studded with lamps) suffered from a low illumination contrast. An improvement raised the letters from the background. Further improvements sunk the letters into the background, and then had the letters illuminated by concealed lamps. Further developments utilized transparent glass or perforated metal letters. A variant had opaque letters raised from the background with lamps installed behind

the letters to illuminate the background and silhouette the letters. A danger of illuminated signs is that they may not be legible in the daylight if messages overlap or contrast is poor.

2. "(R)ange or visibility of an uncolored light-source increases with its candle-power." (p. 252)
3. "(L)egibility also depends upon the size of the letters and to the relation of the width of the lines comprising the letter to the size of the letter." (p. 252)
4. "The atmosphere containing dust and smoke absorbs blue and blue-green light . . . . For this reason the rank of colored lights of equal candlepower according to range of visibility is as follows: red, orange, yellow, green, blue. Of course, if colorless lamps of equal candlepower are covered with colored glass caps, the range of each will not only be determined by the color but also by the brightness. . . The rank as to range of visibility will (then) be approximately as follows: yellow, orange, red, green, blue. . . based upon the assumption that these colors are of equal purity or saturation." (p. 252)
5. Reporting on the work done by C.A. Atherton, the relative legibility of GOTHIC (sanserif) letters is shown as being in the following order: A, I, J, L, T, M/W, V/X, C/U, K/O/Q, F/P/Y, D, Z, E/N, R, S, G/H, and B.
6. "The attention-value (which is not the same as but holds an intimate relation to legibility) of an electric sign increases with its brightness . . . . However, in signs with small (not necessarily lower-case) letters there is a point at which another increase in the size of lamps produces so much halation or irradiation that the letters 'melt' or run together. . . (producing) low legibility." (p. 253-254)
7. "Lettering and pictorial representation must be simple in the bright . . . sign or there is great risk of illegibility. This is a limitation that the designer may counterbalance with the effectiveness of color and motion . . . . There is no question as to the attention-value of motion but it seems unnecessary to resort to it excepting in the case of powerful competition of neighboring signs." (p. 254)
8. "Colored lights of moderate tints carry further than the pure colors and have the advantage of not being too harsh in brightness-contrast as well as in color-contrast. (However) (i)f pure colors are to be used the bright color should . . . carry the . . . message." (p. 255)

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2185 Luckiesh-1937a
Luckiesh, Matthew and Moss, Frank K.
THE SCIENCE OF SEEING
New York, D. Van Nostrand, 1937, 548 p.

Problem: Study and report on the "science" of vision as a human function, including the visual task of reading.

Procedure: The following outline of contents gives an indication of the book's breadth:

I. Seeing, including evolution of vision, learning to see, light and brightness outdoors, seeing in modern civilization, and seeing is more than vision.

II. The human seeing-machine, including visibility and human beings, various thresholds of seeing, optimum conditions for seeing, correlations, and controllable factors in seeing.

III. Visual sensory processes, including retinal functions, neural pathways and activities, pupillary phonomena, the eyelids, orientation and convergence, binocular vision, accommodation, sensation, perception, and color vision.

IV. Visual thresholds, including significance of threshold functions in seeing, characteristics of visual thresholds, parameters of the visual threshold, interrelationships between fundamental variables, interpretation of threshold data, energy thresholds, various perceptual thresholds, and the effects of attention and distraction upon visual thresholds.

V. Visibility of objects, including the measure of visibility, the Luckiesh-Moss Visibility Meter, the variability of threshold measurements, precision of visibility measurements, human characteristics and deficiencies, visual factors of safety, and visibility and ease of seeing.

VI. Physiological effects of seeing, including nervous muscular tension, visual effort and the heart-rate, the eyelid reflex in critical seeing, fatigue of the extrinsic muscles, pupil size and ocular fatigue, and visual functions and rate of working.

VII. Conservation and achievement, including conservation of vision, education and seeing, work-world efficiency, safety and seeing, and demonstrations of seeing.

VIII. Light and lighting, including light versus lighting, level of illumination, illumination and brightness, backgrounds for seeing, specular reflection, shadows, reflection of light, definitions and units, measurement of footcandles, and measurement of brightness and reflection-factor.

IX. Prescribing light, including effectiveness of footcandles, a standard of visibility, footcandle-levels, footcandle prescriptions, footcandles for reading, individual selection of footcandle-levels, prescribing for defective vision, and high levels of illumination.

X. Quality of lighting, including basic considerations, adaptation and brightness, pupillary criteria, influence of surroundings, psychological effects, glare, and appraising lighting conditions.

XI. Spectral quality of light, including chromatic aberration and visual acuity, common illuminants, seeing in mercury and in sodium light, color-discrimination -matching and -contrast, selectivity of the atmosphere, colored eyeglasses and printing papers, glare and colored lights, and ultraviolet and infrared energy.

XII. Reading as a task, including typography, illumination, reading distance, posture, eye-movements, perceptual factors, and ocular deficiencies.

XIII. Eyesight and seeing, including sensitometric measurements, the control of dynamic accommodation, visual efficiency and ocular comfort, sensitometric criteria in refraction, orthoptic training, and visual efficiency.

Chapter XII (reading as a task) is more concerned with the problems of typographic visibility, legibility, and readability than the other parts of the book. However, the entire work bears on the basic problems of seeing; all of which have some bearing on the above

problems. Reading, then, is detailed in the sense that "it constitutes a critical, uniform and highly controllable visual task." (p. 454) About the task, some general observations are made:

1. "(T)he characteristics of printed or written material are not completely describable in terms of the visibility of single letters or characters. In opthalmology, for example, it has long been known that identical visual acuity ratings are not necessarily obtained when single letters and a line of letters of the same size, respectively, are viewed by the patient.
2. "The influence of intellect, experience and education is generally more prominent in readability than in visibility. As this difference decreases readability and visibility tend to become equivalent." (p. 455)
3. Comparisons are made concerning the differences in validity between objective experimentation and subjective "esthetic comfort" reactions.

From these and several other general observations, a review of others' and the authors' own previous experimental findings are shown.

Result: Specific observations pertinent to visibility, legibility, and (primarily) readability, then, are as follows:

1. "OLD ENGLISH and MODERN GOTHIC letters are not equally readable to one who is not familiar with the former.
2. "(I)t would seem obvious that a monogram is not as readable as one of the letters even though the two are of identical visibility as appraised by threshold measurements . . . .
3. "(T)he average visibility of the lower case letters of seven modern typefaces was about 40 per cent higher for isolated than for grouped letters. This value varied from 30 to 56 per cent for the individual type-faces . . . .
4. "(I)f two types were equally visible, it seems reasonable . . . that the one which yielded the highest integrated reflectance (type and background) would be preferred. However, actual measurement . . . indicated that the differences . . . are not large.
5. Measurement of "psychophysical effects of seeing . . . are too unwieldy to be used in practice . . . ." However, "measurements of visual function (viz. speed of reading accuracy in reading and eye-movements) . . . as criteria of readability. . . are rather insensitive to the differences in readability produced by moderate changes in type-face.
6. "(T)he relationship between type-size and visibility as determined by adult subjects possessing normal or near-normal vision. . . is a linear one . . . probably . . . due to empirical factors involved in the design of this particular series (BODONI) of types . . . .
7. "3-point type is about the smallest which unaided eyes may (normally) resolve . . . .
8. "12-point type (illuminated by 10 footcandles) represents a practical optimum . . . (T)ype of this size has a relative visibility of about 5.7 or . . . threshold visibility to a person with a visual efficiency rating of about 44 per cent, . . . . This is less than 20/100 . . . .
9. "(A)n ideal standard of visibility is far above the average type in newspapers.
10. "24-point type is the largest size practicable" for reading.
11. "The degree of visibility, for a given type-size, is also a function of the pattern or configuration of the type-face. . . (R)elative visibilities of a series of 20 different 8-point type-faces" (p. 456-462) is as follows (determined with the Luckiesh-Moss Visibility Meter):

| type-face | per cent visibility |
|---|---|
| BODONI BOOK | 100.0 |
| BODONI BOOK ITALIC | 96.0 |
| BODONI BOLD | 108.3 |
| CASLON LIGHT | 96.2 |
| CASLON LIGHT ITALIC | 81.1 |
| CASLON BOLD | 106.5 |
| SANS SERIF LIGHT | 97.1 |
| SANS SERIF MEDIUM | 105.7 |
| SANS SERIF BOLD | 104.3 |
| CHELTENHAM WIDE | 100.5 |
| CHELTENHAM BOLD | 108.5 |
| CHELTENHAM BOLD CONDENSED | 93.2 |
| LIGHT COPPERPLATE GOTHIC | 98.1 |
| HEAVY COPPERPLATE GOTHIC | 102.5 |
| GOUDY LIGHT | 94.0 |
| GOUDY ANTIQUE | 106.2 |
| GOUDY BOLD | 104.8 |
| COCHIN LIGHT | 102.3 |
| COCHIN BOLD | 112.6 |
| GARAMOND BOLD | 118.7 |

12. "Novelty (e.g. boldness and italics) . . . in large portions of text . . . is (not) obtained without significant sacrifices in ease of seeing and reading." (p. 462)
13. "(C)oncerning the optimum length of line, . . . consensus indicates . . . (no) longer than ten centimeters. . . Upon the basis of speed of reading, . . . 7.5 to 9 centimeters.
14. "(U)sing speed of reading as a criterion, . . . optimum interlinage (leading) was: approximately 1/10 inch for 12-point type, 1/14 inch for 9-point type, and 1/17 inch for 6-point type.
15. "Footcandles necessary for various sizes of type to equal a given standard of visibility" (p. 466-467) are as follows:

| standard (BODONI BOOK) | 12-pt. | 10-pt. | 8-pt. | 6-pt. |
|---|---|---|---|---|
| 5 ft.-cdls. on 12-pt. | 5 | 7 | 10 | 17 |
| 10 " " " " | 10 | 15 | 21 | 36 |
| 20 " " " " | 20 | 28 | 42 | 68 |
| 50 " " " " | 50 | 71 | 93 | 167. |

16. "(R)eaders with normal eyesight and normal eye-movements showed little variation (in fixational-pauses) between 6-point and 36-point type," (p. 470) but a great deal of difference between various types of reading content, familiarity and language, and age.
17. "(R)ather small differences in the (time-dependent) frequencies of . . . eye-movements were obtained under . . . lighting conditions" (p. 475) of 0.25 and 5 footcandles.
18. "(S)peed of reading decreased about ten per cent during (a 2-hour) period." (p. 476)
19. "(O)cular muscle activity . . . increased from 9 to 13 from the beginning to the end of the (2-hour) period of reading." (p. 477)
20. In perceptual span, "the average reader, for a tachistoscopic exposure of 0.01 (seconds?), could perceive three of four single letters, two disconnected words containing as many as twelve letters, or a sentence of four words.
21. "(I)t requires several times as much light on numerals such as stock-market quotations to make their visibility the same as that of words printed in the same

size of type and upon the same sheet of paper." (p. 479)

22. "Approximate number of letters in a single horizontal which may be seen by foveal (acute vision afforded by the small rodless area of the retina) and macular (perceived by the yellow spot on the retina) vision at a reading distance of 14 inches" (p. 480) is as follows:

| | 6-pt. | 8-pt. | 10-pt. | 12-pt. |
|---|---|---|---|---|
| foveal | 6 | 5 | 4 | 3.5 |
| macular | 66 | 51 | 45 | 38 |

23. "(S)peed of perception in reading is independent of retinal sensory functions and must depend upon central nervous processes." However, "the possible advantages of enlarging the perceptual span . . . may be discounted by the possibility of accompanying ocular anomalies.
24. "In general, it would seem better to obtain the desired degree of visibility by means of higher levels of illumination rather than by unusually large type . . ., " particularly to compensate for visual defects (nystagmus may be an exception).
25. "A survey of 10,000 school-children . . . established definite correlation between rate of reading and visual efficiency." (p. 480-482)

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2184 Luckiesh-1937c

Luckiesh, Matthew
General Electric Co., Cleveland, Ohio
THE PERFECT READING PAGE
Electrical Engineering, 56:7 (July 1937) 779-781

Problem: Discuss "the factors that would influence the production of a perfect reading page, and an opinion, founded upon scientific research, concerning this 'easy reading' page as an approximation of the theoretical ideal." (p. 779)

Procedure: "The visibility of objects depends primarily upon
1. Size of the critical details.
2. Contrast between the object and background.
3. Brightness of the object and background, which depends upon the reflection factor and intensity of illumination.
4. Time available for recognizing the object.

"In general, the theoretically ideal printing page results from
1. Large type of the most legible style.
2. Paper of high reflection factor and dull surface. If it is tinted, it should be optically and aesthetically satisfactory.
3. High level of illumination comparable to that in the shade of a tree or porch.
4. Time usually is not of great importance, if other factors are satisfactory." (p. 779)

Result: The following specific observations concern various aspects of the "components of the perfect reading page." (p. 779)
1. Fixation pauses - "(D)uration of the fixational pause . . . has been found to vary chiefly between 0.07 and 0.30 second. . . Words, or even groups of them, are seen at each pause. The number of stops made in reading a line depends upon visibility, familiarity, practice, and intelligence . . . .
2. Type size - "12-point type may be concluded to be quite satisfactory for continued reading. Newspapers commonly are set in 8-point type, with parts of them in 6-point type.

3. Type style - "The effect . . . on legibility is a complex matter, but long experience has evolved satisfactory styles devoid of needless details and with an openness necessary for good legibility.
4. Contrast - The formula for computing percentage contrast ratio is as follows:
$$100 \times \frac{\text{(background - object) brightness}}{\text{background brightness}}$$
"Usually the nearest approach is a contrast of about 97 per cent. For a telephone directory the contrast . . . is about 80 per cent, and for the better examples of newsprint about 85 per cent. . . Any color, even a light tint, added to white paper decreases the contrast slightly; however, the extent to which this decrease causes a decrease in visibility should be considered in weighing this against other considerations. . . Although contrast is very important in the visibility of objects, it is of only slight importance in the range of high contrasts . . . The loss in contrast is very slight in a white paper tinted yellow, and is less in ordinary artificial light than in daylight.
5. Color - "There can be no justification for the use of highly colored paper for pages that must be read for extended periods; furthermore, from purely the optics of the eye, blue, violet, purple, and pink papers are inadvisable. Normal eyes cannot focus blue light at the usual reading distance. . . (E)limination of the blue and violet components of light does not decrease visibility appreciably . . . (A) yellowish tint is better than any other." There are "other reasons for using a slightly yellowish paper . . . . It does not decrease visibility appreciably because of its slightly lower reflection factor and the consequent slightly lower contrast; moreover, its color is in the right direction from the viewpoint of chromatic aberration of the eye." Also, there seems to be some basis for esthetically preferring "a slightly yellowish tint.
6. Reflection - "Glossy paper may reflect bright, imperfect images into the eye; dull paper is ideal . . . Many white papers have reflection factors of from 80 to 85 per cent . . . ." A difference in reflection factors of 76 (percent) and 73 (percent) (ordinary tungsten-filament---slightly greater difference for daylight) for sepia-tinted paper gave no significant difference in the visibility of print thereon (using the Luckiesh-Moss Visibility Meter).
7. Contrast vs. reflection - "The reflection factor of a paper having a slight . . . tint is a few per cent less than it would be if the tint were eliminated, thus reducing the brightness (and hence contrast) of the paper under a given intensity of illumination by an amount exactly proportional to the reduction in reflection factor.
8. Illumination - "One foot-candle . . . is a common illumination indoors. The general average in the indoor world is less than 5 foot-candles where reading is done. Near a window in the daytime there is commonly an illumination of several hundred foot-candles. . . Experiments have indicated that while the subjects read a book printed in 12-point type on excellent dull, white paper, the ease of reading continues to increase up to at least 1,000 foot-candles.
9. Illumination vs. type size - "12-point type could be read at one foot-candle.
10. Psycho-physical response - Nervous muscular tension resulting from visual work can be measured at the finger tips.

The following general observations also were made:

1. "(E)ase of reading cannot be judged by visibility, and the mere possibility of seeing provides no reason for believing that further improvement in seeing is of no value.
2. "Feelings are just as real as any reality . . . .
3. "(K)nowledge (in the legibility of printed materials) springs both from controlled researches and mass experience." (p. 779-781)

* * *

2566 Luckiesh-1940a

Luckiesh, Matthew and Moss, Frank K.
General Electric Co., Cleveland, Ohio
BOLDNESS AS A FACTOR IN TYPE-DESIGN AND TYPOGRAPHY
Journal of Applied Psychology, 24:2
(April 1940) 170-183

Problem: Determine "the optimum degree of boldness for (the MEMPHIS) family of 10-point types as indicated by the criteria of visibility (measured by the Luckiesh-Moss visibility meter) and readability (rate of involuntary blinking)." (p. 170) A secondary "objective . . . (was) the determination of the extent to which visibility measurements indicate the attribute of readability as the latter is influenced by boldness." (sic) (p. 171)

Procedure: First, "a precise photometric method for appraising the relative boldness of types of the same size and amount of leading.". . (p. 171) was derived. Data extracted from tests of the MEMPHIS family indicated that the boldness of the members, as indicated by the designations LIGHT, MEDIUM, BOLD, and EXTRA BOLD, "does not increase exactly in either an arithmetic or a geometric progression(, w)hile . . . it is a well-known fact that visual sensation (visibility) increases arithmetically with geometric increases in the intensity of the stimulus (boldness of type in this case)." (p. 173) Then, "(t)he relative visibilities of the four weights of 10-point MEMPHIS type . . . (were) determined with the Luckiesh-Moss visibility meter .". . (p. 174) by five observers under a diffuse illumination of 10 footcandles. After that, a speed-of-reading test was utilized on 40 subjects to determine "readability" of the faces. "Since the rate of involuntary blinking has been shown to increase when conditions for critical seeing are made for more unfavorable, * it is reasonable to assume that this criterion is a reliable one for appraising the influence of boldness upon readability in any family of types for body-text. . . In obtaining (the) data (from this test), each subject read each of the four types (printed on dull white paper) for 5-minute periods on two different occasions . . . under a diffuse illumination of 10 foot-candles." (p. 176) Finally, as a result of the experiments delineated by this paper, "the investigation was repeated by a different experimenter under the following conditions: 1. In a different laboratory and under . . . 5 footcandles . . . . 2. The order of presenting the several weights of MEMPHIS types was altered. . . 3. The measurements were made with 18 instead of 40 subjects . . . ." (p. 180)

Result: In the visibility test, "the relative visibilities of MEMPHIS LIGHT, MEMPHIS MEDIUM, and MEMPHIS BOLD (were) 100, 114, and 116, respectively." (p. 175) On a comparative basis, "the (MEMPHIS) EXTRA BOLD . . . (gave) a relative visibility of 115.5. . . The outstandingly important fact revealed by the visibility-boldness relationship is the definite indication of an optimum boldness. . . (I)t appears that . . . (this) is obtained with MEMPHIS MEDIUM . . . (S)uch an increment . . . (however) is not significant from statistical or practical viewpoints. . . (I)t is probable that other commonly used type-faces . . . would vary similarly in visibility. . . In any event, the potential enhancement in visibility appears to be an important one.". . (p. 176) from a type design viewpoint. In the readability test, the following relative rates of blinking were determined (low numbers best):

| | MEMPHIS LIGHT | MEMPHIS MEDIUM | MEMPHIS BOLD | MEMPHIS EXTRA BOLD |
|---|---|---|---|---|
| arithmetic mean | 100.0 | 90.4 | 96.0 | 101.5 |
| geometric mean | 100.0 | 88.1 | 94.3 | 99.1 |

(above from p. 177)

"It will be noted . . . that about the same relative rates of blinking were obtained by both methods of averaging . . . It will also be noted that the differences . . . are quite significant . . . ." (p. 177) From a comparison of the visibility versus readability tests,

the following conclusions were drawn:

1. "The optimum degree of boldness, as indicated by the criterion of readability, is obtained with MEMPHIS MEDIUM;
2. "The optimum degree of boldness is much more sharply defined by the criterion of readability than by that of visibility;
3. "A somewhat bolder type is indicated by the criterion of visibility than by . . . readability. . ." (p. 178)

"In view of . . . complex relationships, it seems obvious that introspective methods for appraising the influence of boldness can possess little intrinsic significance and reliability. It should also be obvious that utilitarian aspects of type and typography are not appraisable by the esthetic sense." (sic) (p. 179) "(F)rom the practical viewpoint of type-design, an important contribution of readability criteria lies in the confirmation of the appropriateness of visibility measurements under certain definite conditions and limitations. In the absence of additional data, these conclusions are at present restricted to 10-point types set with 2 points of leading . . . ." (p. 179) In the test by the independent investigator, the results showed no statistically significant variation from the blink-rate test conducted here. And finally, the following general conclusions were drawn "pertaining to the utilitarian merit of various type-faces . . .:

1. "A marked enhancement in the readability of the printed page can be obtained by augmenting the boldness of many types which are now being recommended or widely used for body text.
2. "An enhancement in readability is decisively less promising by means of alterations in the configuration of many commonly used type-faces than by utilizing the optimum degree of boldness.
3. "The design of a type of optimum readability may now be guided with reliability and exactness by measurements of visibility within a range which is now fairly definitely known.
4. "The rate of involuntary blinking while reading under controlled conditions appears to be well established as a criterion of readability. . .

"(T)hese conclusions are based upon the intrinsic visibility of the types studied and upon the facility with which they are actually read and not upon introspective appraisals of the appearance of the printed page." (p. 182)

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* By: (1) decreasing the illumination, (2) increasing the duration of the task, (3) the presence of glare, (4) increasing the contrast between task and surroundings, (5) flickering illumination, (6) erroneous eyeglasses, (7) increasing extrinsic muscle effort, (8) decreasing size of type, (9) decreasing the leading, (10) use of colored backgrounds, (11) inferior printing, (12) altering type-face, etc. (p. 176)

* * *

3348 Luckiesh-1940b

Luckiesh, Matthew and Moss, Frank K.
General Electric Co., Cleveland, Ohio
CRITERIA OF READABILITY
Journal of Experimental Psychology, 27:3
(September 1940) 256-270, 11 refs.

Summary: "Readability has been defined as an attribute of the physical characteristics of the materials read and has been appraised, on this basis, by the criteria of rate of reading and rate of involuntary blinking while reading. The results of a series of carefully controlled investigations, involving diverse visual variables, reveal that the normal rate of reading is an insensitive indicator of readability as compared with rate of blinking. Furthermore, the appraisals of readability by the two criteria are frequently in disagreement. Whether or not the criterion of involuntary blinking adequately appraises all factors involved in readability, it appears to be far more significant, from both

theoretical and experimental viewpoints, than the criterion of rate of reading." (p. 269)

Review: The results of previous investigations that used relative rates of blinking as the experimental criteria are shown as follows:

| variable | relative rate of blinking | | | |
|---|---|---|---|---|
| illumination on book (one hour of reading) | 100<br>(100 fc) | 118<br>(10 fc) | 154<br>(1 fc) | |
| duration of reading (first and last 5-min. of 1 hour) | 100/108<br>(100 fc) | 100/131<br>(10 fc) | 100/171<br>(1 fc) | |
| glare while reading (25 L. at 20 degrees) | 100<br>without | 156<br>with | | |
| eyeglasses worn while reading | 152<br>+0.5 D. | 100<br>correct | 145<br>-0.5 D. | |
| type-size of text matter | 100<br>12-point | 148<br>6-point | | |
| type-face of text matter | 100<br>bold | 110<br>medium | 118<br>light | |
| color of paper of printed text matter | 100<br>white | 99<br>cream | 111<br>yellow | 118<br>red |
| leading of type read | 100<br>6-point | 104<br>3-point | 111<br>2-point | 123<br>solid-set |
| task requiring rapid shifts in fixation (periods of 5-minutes of task) | 100<br>first | 146<br>second | 171<br>third | |
| illumination of surroundings (10 FL. on book) | 111<br>0.2 | 100<br>1 | 108<br>5 | 116<br>25 |
| | brightness ratio, central : surroundings | | | |

(above from p. 258)

In addition, the following tables show relative rates of reading and blinking for the experiments and variables indicated:

Material: "Outline of History"---Wells. Book form. Non-glossy black ink on non-glossy white paper.
Type: 10-point DE VINNE; 1-point leading; 24 pica lines
Tests: Two 5-minute periods by each of 10 subjects.

| Relative rate of reading: | 100 | 102.7 | 107.9 |
|---|---|---|---|
| | at 1 f-c | at 10 f-c | at 100 f-c |

Material: "Why We Behave Like Human Beings"---Dorsey. Book form. Non-glossy black ink on non-glossy white paper.
Type: 12-point BODONI BOOK; 1-point leading; 22 pica lines.
Tests: Eight 30-minute periods by each of 14 subjects.

| Relative rate of reading: | 100 | 102.9 | 104.7 |
|---|---|---|---|
| | at 1 f-c | at 10 f-c | at 100 f-c |

Luckiesh-1940b

Material: "Outline of History"---Wells. Book form. Non glossy black ink on Non-glossy white paper.
Type: 10-point DE VINNE; 1-point leading; 24 pica lines.
Tests: Five 60-minute periods by each of 7 subjects.

| | | |
|---|---|---|
| Relative rate of reading: | 100 | 107.0 |
| | at 1 f-c | at 100 f-c |

Experiment: The values involve the arithmetic mean of four tests for each individual and the geometric mean of the data from 25 subjects obtained under each condition of lighting during 5-minute reading periods.

| | | | | | |
|---|---|---|---|---|---|
| Relative rate of reading: | 101.6 | 100.0 | 101.2 | 99.6 | 102.7 |
| Relative rate of blinking: | 111.4 | 100.0 | 108.4 | 116.4 | 125.1 |
| each at brightness-ratios (book/surrounds) of: | 0.2 | 1 | 5 | 25 | 125 |

Experiment: The data were obtained from 30 subjects each of whom read 10-point TEXTYPE composed in 21 pica lines under a constant diffuse illumination of 10 footcandles in 5-minute reading periods.

| | | | | | |
|---|---|---|---|---|---|
| Relative rate of reading: | 100.0 | 98.8 | 99.6 | 100.8 | 101.1 |
| Relative rate of blinking: | 100.0 | 99.6 | 90.3 | 84.1 | 81.2 |
| each at the following points of leading: | 0 | 1 | 2 | 3 | 6 |

Experiment: Average maximal rates of reading 10-point type as obtained with 10 subjects each of whom read each material on 5 different occasions.

| | | | | | |
|---|---|---|---|---|---|
| Relative rate of reading: | 100.0 | 97.2 | 98.8 | 97.6 | 99.3 |
| at the following points of leading: | 0 | 1 | 2 | 3 | 6 |

Experiment: The averages were obtained from 40 subjects each of whom read each of the materials on two different occasions under a constant level of diffuse lighting of 10 footcandles. All reading periods were 5 minutes in duration.

| | | | | |
|---|---|---|---|---|
| Relative rate of reading: | 100.0 | 103.2 | 103.5 | 101.8 |
| Relative rate of blinking: | 100.0 | 88.1 | 94.3 | 99.1 |
| each at the following weights of type-face: | light | medium | bold | extra-bold |

Experiment: The following data were derived from experiments in a different laboratory (than for the experiment immediately above) using 18 subjects under 5 foot-candles of illumination. The same materials were read.

| | | | |
|---|---|---|---|
| Relative rate of blinking: | | | |
| arithmetic means | | | |
| first test: | 100.0 | 90.4 | 96.0 |
| second test: | 100.0 | 88.9 | 94.5 |
| geometric means | | | |
| first test: | 100.0 | 88.1 | 94.3 |
| second test: | 100.0 | 88.8 | 95.0 |
| at the following weights of type-face: | light | medium | bold |

Experiment: The data represent the average results obtained in two separate investigations involving 12 subjects each reading materials printed in 10-point TEXTYPE with 2 points of leading and in black ink on non-glossy white paper under 10 footcandles.

| | | | | | |
|---|---|---|---|---|---|
| Relative rate of reading: | 100.0 | 97.2 | 96.7 | 98.0 | 99.6 |
| Relative rate of blinking: | 100.0 | 110.4 | 122.0 | 118.2 | 119.5 |
| each in the following line-lengths (picas): | 13 | 17 | 21 | 25 | 29 |

(above experiments from p. 259-268)

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2122 Luckiesh-1941b

Luckiesh, Matthew and Moss, Frank K.
General Electric Co.
THE EXTENT OF THE PERCEPTUAL SPAN IN READING
Journal of General Psychology, 25:2
(October 1941) 267-273

Problem: Determine whether "the extent of the average perceptual span is . . . constant" (p. 267) or variable, with respect to type size and line length, for the normal reading situation.

Procedure: "(D)ata pertaining to the average number of characters read during a fixational pause were determined from numerous records of the eye-movements obtained while the subjects (selected at random from technical and clerical groups. . . possess(ing) normal vision and . . . better than average ability in reading) read under normal conditions (simulated in the laboratory) of posture, fixational distance, illumination (10 foot-candles diffuse), etc." (p. 267-268) Data were recorded by measuring electrical potential between the temple and forehead. "(R)eading matter may be described as informative and not of an emotional character." (p. 267-268) In the type size experiment, the CENTURY EXPANDED face was used. Its characteristics and layout were as follows:

| size (in points) | 4 | 6 | 8 | 10 |
|---|---|---|---|---|
| characters (including spaces) per line | 57 | 48 | 39 | 34 |
| lower case alphabet length (in points) | 78 | 95 | 119 | 142 |
| line length (in picas) | 14 | 14 | 14 | 14 |
| leading (in points) | 1 | 1 | 1 | 1 |

"(Twenty) lines of print (were scored) for each eight subjects." (p. 269) In the line-length experiment, subjects read from Well's Outline of History in 10-point TEXTYPE with line lengths of 13, 21, and 29 picas (2-point leading between lines).

Result: "It is the consensus of several investigators that the number of characters perceived or 'read' during a single fixational pause . . . is not appreciably influenced by factors such as size of type, level of illumination, etc. . . In general, (our) data confirm the conclusion that the . . . span is quite constant . . . insofar as it depends upon strictly perceptual factors. However, . . . the number of characters read during a single average fixation depends to some (small) extent upon the physical characteristics of the text. . . (p. 267) (E)rratic eye-movements and a more oblique line of vision in the case of the longer lines, might increase the number of characters included in (a) fixation. On the other hand, (an) increase in the number of hyphenated words might produce a decrease in the number of characters per span in the . . . shorter lines." (p. 271) The following

specific results were shown:

1. "(T)he number of characters per fixation decreases (but not monotonically) from 8.50 to 7.84 as the type-size is increased from 4 to 10 points . . . ." (p. 272)
2. "(T)he span increases from 8.14 to 9.31 characters as the line-length of 10-point matter is increased from 13 to 29 picas." (p. 272) Thus, "the average number of fixations increases as the line-length increases, but not in direct proportion." (p. 270) In addition, it was ascertained that "13-pica lines are easier to read than 29-pica lines under otherwise identical conditions." (p. 272)
3. "The average of all . . . data indicates a span of about 8.5 characters during an 'average' fixation . . . . The maximum variation from this . . . is 0.8 of one character per fixation or about 10 per cent of the average value." (p. 272)

"(I)t seems reasonable to conclude that the number of characters recognized in a 'typical' fixation is substantially independent of type-size and of line-length in the case of readers of the type involved in this research." (p. 272)

* * *

2182 Luckiesh-1942

Luckiesh, Matthew and Moss, Frank K.
READING AS A VISUAL TASK
New York, D. Van Nostrand Co., Inc., 1942, 428 p.

Extract: "(T)he authors have dealt primarily with reading as a visual task and with the various controllable factors which influence ease of seeing. The results presented . . . are confined chiefly to the authors' work and entirely to reading as a visual task. Other aspects, such as retention and reading disabilities, are beyond the boundaries of their work." (p. v) Following is an outline of contents of this quite comprehensive work:

- I. The task of reading.
  - A. General (reading may be defined as the visual reception and understanding of words or other symbols).
  - B. An unnatural task.
  - C. Visibility and readability.
  - D. Reading efficiency (including figure 1---a diagrammatic view of the relation of any aid to seeing to the expenditure of human resources in the performance of any task of seeing).
  - E. Need for measurements.
  - F. Reading a line of print (including figure 2---an electromyogram made while a typical educated adult subject read two consecutive lines of print).
  - G. Fixations and regressions (including figure 3---a summary of data from many electromyograms made while adult subjects read for one hour).
  - H. Reading and other muscular tasks.
  - I. The brain as a taskmaster (including figure 4---comparing the demands of the brain upon the functioning of the heart and eyes).
- II. Aids to seeing.
  - A. General.
  - B. The visual sense.
  - C. Young eyes (including figure 5---the development of binocular vision in early childhood; and figure 6---the influence of age and training upon the character of the eye-movements in reading).
  - D. Controllable aids to reading (including figure 7---a diagrammatic view of the controllable factors in seeing balanced against a given visual task considered in its extended sense which includes the vagaries, limitations, and abilities of the human being, the characteristics and requirements of performance and the environment as it affects visibility and the human

seeing machine).

E. Four fundamental factors (including figure 8---illustrating the relations among the fundamental visual factors of size, contrast, brightness, and time; and figure 9---the threshold relationship between contrast and size for three levels of brightness).

F. Physical and visual size.

G. Brightness-contrast (including the formula---

$$\text{percent contrast} = 100 \times \frac{\text{object brightness - background brightness;}}{\text{object brightness}}$$

and figure 10---the relation between measurements of visual function determined from contrast-thresholds and visual acuity thresholds).

H. Brightness.

I. Duration of retinal impression.

J. Light, lighting, and brightness (the level of illumination or brightness of the printed page, the brightness of the area immediately surrounding the printed page, and the brightnesses in the remainder of the peripheral visual field).

K. Illumination and brightness.

L. Brightness and surroundings (including figure 11---a diagrammatic presentation of the rivalry between peripheral and central stimuli for visual fixation and mental attention).

M. Papers and inks.

N. Quality of printing.

O. Eyeglasses.

P. Any aid to seeing (including figure 12---the degree of utilization of any aid to seeing is represented).

III. Visibility.

A. General.

B. Visibility measurements.

C. The visibility meter (including figure 13---the portable Luckiesh-Moss Visibility Meter; and figure 14---the two identical gradient filters of the L-M Visibility Meter, calibrated in relative footcandles and relative visibility).

D. Scale of relative visibility (including figure 15---reproductions of the parallel-bar test-objects used in calibrating the L-M Visibility Meter; figure 16---illustrating the visibility of various sizes of type in terms of the standard parallel-bar test-object; and table 1---the order of magnitude of the probable error of typical measurements of visibility with the L-M Visibility Meter made under well-controlled laboratory conditions).

E. Primary scale of supra-threshold visibility (including figure 17---the threshold relationship between size and contrast plotted on logarithmic coordinates).

F. Modified scale of supra-threshold visibility (including figure 18---threshold relationship between size and contrast plotted on arithmetic coordinates; figure 19---the modified scale of supra-threshold visibility, showing a translation from threshold to supra-threshold visibility by arithmetic rather than by geometric means; and table 2---the relationships between the scales of relative visibility and percent maximal visibility).

G. A comparison of the primary and modified scales (including table 3---visibility values obtained with the L-M Visibility Meter under a diffuse illumination of 10 footcandles).

H. Empirical scales of visibility.

1. Equivalent type size (including figure 20---the relative visibility of BODONI BOOK type face in points and under various levels of illumination, and the relationship between relative visibility and percent maximal visibility).

2. Illumination factor (including figure 21---the relative visibility, obtained with the L-M Visibility Meter, of 8-point BODONI BOOK type under various levels of illumination).

IV. Criteria of readability.
  A. General.
  B. Criteria of readability.
  C. Involuntary blinking (including figure 22---the relative rates of blinking while reading as various factors which influence visibility and ease of seeing are varied individually).
  D. Technique of the blink-rate criterion.
  E. The significance of the criterion.
    1. Duration of task.
    2. Type-size.
    3. Refractive errors.
    4. Glare.
    5. Illumination (including table 4---the rates of involuntary blinking during periods of reading under various illumination levels).
  F. Reliability of blink-rate criterion.
    1. Experimental results (including table 5---the relative rates of blinking determined in repeated investigations involving type-face, line-length, and brightness of surroundings as variables).
    2. Individual variations in rate of involuntary blinking.
  G. Speed of reading as a criterion of readability.
    1. Discussion.
    2. Level of illumination (including table 6---the normal rate of reading under various levels of diffuse lighting and for varying length reading periods).
    3. Lighting environment (including table 7---relative rates of reading and blinking for brightness-ratios (book/surrounds) of 0.2, 1, 5, 25, and 125).
    4. Leading of type (including table 8---relative rates of reading and blinking for 0, 1, 2, 3, and 6 points of leading; and table 9---average maximal relative rates of reading for 0, 1, 2, 3, and 6 points of leading).
    5. Boldness of type-face (including table 10---relative rates of reading and blinking for light, medium, bold, and extra-bold type).
    6. Line-length (including table 11---geometric average relative rates of reading and blinking for line-lengths of 13, 17, 21, 25, and 29 picas).
  H. Speed of reading and compensation phenomena (including figure 23---illustrating an experiment which showed the ability of the human seeing-machine to compensate for poor, i. e. vibratory, visual conditions; and figure 24---indicating the relationship between level of illumination and speed of reading OLD ENGLISH type printed with black ink on white and gray paper).
  I. Summary.

V. Size of type.
  A. General.
  B. Type-size and visibility (including table 12---the visibilities of various sizes of BODONI BOOK type expressed on the RV (type-size versus relative visibility) and PMV (type-size versus visibility) scales).
  C. Type-size versus relative visibility (including figure 25---the relative visibility of various sizes of BODONI BOOK type; and table 13---a correlation between the Scale of Relative Visibility (RV) of the L-M Visibility Meter and the Scale of Visual Efficiency of the A. M. A. ).

D. Type-size versus visibility (including figure 26---percent maximal visibility of various sizes of BODONI BOOK type; figure 27---the visibility of various sizes of BODONI BOOK type expressed upon the scales of Relative Visibility and Supra-threshold Visibility; and table 14---the percentages of various assumed standards of visibility obtained with given sizes of type).

E. Type-size and illumination (including figure 28---the percent maximal visibilities of various sizes of BODONI BOOK types under various levels of illumination).

F. Illumination, type-size, and standards of visibility (including table 15---footcandles necessary for various sizes of type to equal a given standard of visibility).

G. Type-size and perceptual span (including table 16---the average number of characters per fixation in reading types varying from 4 to 10 points inclusively).

H. Type-size and reading habits (including figure 29---showing the decrease in the visibility of 10-point type as the plane of the reading material is varied with respect to the so-called normal line of vision).

I. Type-size and readability (including table 17---the visibility and readability of various sizes of TEXTYPE involving line-lengths and leading in accord with modern typographical practice; and figure 30---the relationship between level of illumination and the increase in the rate of involuntary blinking as the result of reading for an hour).

VI. Type-face.

A. General.

B. Visibility of type-faces (including table 18---the relative visibilities of 8-point types expressed on several appropriate scales; table 19---the visibilities of seven common type-faces well printed with black ink on excellent non-glossy white paper; and table 20---the experimental visibility rank of five common type-faces).

C. The readability of various type-faces (including table 21---the relative visibility, rate of blinking, and speed of reading for three, 10-point type-faces; table 22---the geometric mean for the relative visibility, frequency of blinking, and speed of reading for the same faces; and table 23---the rate of blinking and speed of reading for the same faces, obtained in two series of measurements made a month apart).

D. Boldness as a factor in type-design.

E. A measure of boldness (including figure 31---four weights of 10-point MEMPHIS type with two points of leading; table 24---the reflection factor and relative boldness for four weights of MEMPHIS type; table 25---the relative and percent visibility, and the alphabet length/relative character count for the same four weights of MEMPHIS type; and figure 32---the influence of boldness of type as appraised by the criteria of involuntary blinking, visibility, and speed of reading, respectively).

F. The readability of MEMPHIS types (including table 26---arithmetic and geometric means of the relative rates of reading and blinking for the four weights of MEMPHIS type).

G. Speed of reading MEMPHIS type (including table 27---number of lines read and relative rate of reading the four weights of MEMPHIS type in 10-point, by 40 subjects, for 5-minute periods each).

H. Summary pertaining to boldness.

I. Visibility and readability of various type-faces (including table 28---data pertaining to the readability of various type-faces, expressed as a percentage of those obtained with TEXTYPE; and table 29---showing the superiority of 10-point TEXTYPE and MEMPHIS MEDIUM over some

other 10-point types as determined by visibility, blink-rate and a combination of the two).

VII. Leading and line-length.
   A. General.
   B. Leading and readability.
      1. Discussion (including figure 33---ten-point TEXTYPE set with five different degrees of leading and composed in 21-pica lines).
      2. Influence of leading on blink-rate (including figure 34---the relative rate of blinking while reading with various degrees of leading).
      3. Influence of leading on speed of reading (including table 30---average maximum speeds of reading 0-, 1-, 2-, 3-, and 6-point leaded text by 10 adult subjects possessing reasonably normal vision; figure 35---the individual relationships between leading and speed of reading, as determined with 10 subjects; figure 36---the average speed of reading as determined by five subjects for two levels of illumination and various points of leading; and table 31---average normal speeds of reading 0-, 1-, 2-, 3-, and 6-point leaded text by 23 subjects under 5 footcandles).
   C. Conclusions pertaining to leading.
   D. Line-length and readability.
      1. Discussion.
      2. Rate of blinking (including figure 37---the effect of line-length on the rate of blinking while reading 10-point TEXTYPE set with 2 points of leading and composed in various line-lengths; table 32---the geometric average rates of blinking during 5-minute periods of reading 10-point type, with 2 points of leading, and in 13-, 17-, 21-, 25-, and 29-pica line-lengths; and table 33---showing the number of subjects of a total of 24 who blinked faster, the same, or slower while reading 29-pica lines than in reading 13-, 17-, 21-, and 29-pica lines, respectively).
      3. Eye-movements (including table 34---the number of fixations, fixations-span in picas, and relative length of span for 12 subjects reading 15 or more lines of 10-point, 2-point leaded, type in line-lengths of 13, 21, and 29 picas).
      4. Speed of reading (including table 35---geometric averages of rates of reading 10-point, 2-point leaded, type, in line-lengths of 13, 17, 21, 25, and 29 picas by 24 subjects).
   E. Conclusions pertaining to line-length.
   F. Typographical practice.

VIII. Papers and inks.
   A. General.
   B. Diffuse reflection-factor (including figure 38---common reflection characteristics of surfaces).
   C. Diffuse reflection and visibility (including table 36---the rank in visibility of printed matter on nine different specimens of paper; and table 37---the visibility of printed matter on ten different specimens of paper, each diffusely illuminated by 10 footcandles).
   D. Specular reflection-factor (including table 38---specular and diffuse reflection-factors of some common papers and inks; and figure 39---determination of the specular reflection-factor of a glossy paper).
   E. Specular reflection and visibility.
   F. Tinted and colored papers (including figure 40---the diffuse reflection-factors of four different papers for light of various wavelengths throughout the visible spectrum; and table 39---visibility, speed of reading, and readability of 10-point LINOTYPE TEXTYPE printed with non-glossy ink on four specimens of tinted or colored papers).

G. A practical example (including table 40---percent visibilities of the same printed matter with various papers and inks; and table 41---the visibilities, in percent of 10-point EXCELSIOR, of four 10-point and one 11-point type).
H. Letterheads (including table 42---a comparison of the same typewritten material on white and on blue letterheads).
I. Advertising material (including table 43---a comparison of results of printing the same material on red and on white papers).
J. Level of illumination.
K. Quality of lighting (including figure 41---illustrating the effect of specular reflection-factors of paper and ink upon the brightness-contrast between paper and ink for light-sources of three different brightnesses at various levels of diffuse illumination).

IX. Various duplicated materials.
A. General.
B. Glimpses of processes.
C. Stencil-duplicated materials (including figure 42---specimens of average and superior duplicated reading material; table 44---the rate of involuntary blinking for 12 subjects who read average and superior stencil-duplicated materials for 30-minute periods; table 45---the rate of reading for 12 subjects for two qualities of stencil-duplicated materials compared with visibility and rate of blinking; figure 43---typical electromyograms for an educated adult reader whose eye-movements in reading are characteristically somewhat erratic; and figure 44---typical electromyograms for an educated adult reader whose eye-movements are characteristically fairly rhythmic with well-defined fixations).
D. Typewritten material (including table 46---a comparison of two typewriter types, scaled down to 10-point in size, with 10-point metal types commonly used in printing, all leaded 2 points; and table 47---comparative visibility data pertaining to typewritten originals and carbon copies of very good quality, specimens of which were backed with both white and black cardboard).
E. Hectograph duplication (including table 48---illustrating the variation in hectograph reproductions with ELITE TYPEWRITER type).
F. Offset printing.
G. Other materials.
H. Hand-lettering (including table 49---relative visibility data obtained for 24 samples from run-of-the-mill comic books compared with a standard consisting of 12-point BODONI BOOK type well printed with black ink on excellent white paper, all samples being under an illumination of 20 footcandles; table 50---relative visibility data obtained for 24 samples from three of the relatively few comic books in which obvious effort has been made to improve visibility and readability, again under an illumination of 20 footcandles for all samples; figure 45---scale indications of the visibility of various sizes of BODONI BOOK type, printed in black ink on a good grade of white paper and illuminated to 20 footcandles; figure 46---footcandle scale indicating the levels of illumination required upon various comic books in order that the lettering be as visible as 12-point BODONI BOOK type, well-printed with black ink on white paper, under an illumination of 20 footcandles; and table 51---averages of values of samples in tables 49 and 50 compared with each other and with the standard 12-point BODONI BOOK type well printed with black on thick white paper).

X. Visual efficiencies and deficiencies.
A. General (including figure 47---approximate percentages of persons having defective vision in various age-groups in the work-world and also in schools and colleges; and figure 48---the impairment in visual functions

and visual abilities as the eyes grow older).

B. Visual deficiencies and refractive errors (including figure 49---the percentage loss in visibility resulting from uncorrected refractive errors of various magnitudes as determined with the L-M ophthalmic sensitometer; figure 50---the percentage loss in visibility resulting from various uncorrected refractive errors, also expressed in terms of decreasing type-size; figure 51---the relative visibilities of a given test-object with myopic and hyperopic errors of various magnitudes, as determined under various brightness-levels, also indicating the variability of unit size in visual effectiveness; and figure 52---electromyograms obtained during reading by an emmetropic subject and by the same subject while wearing -0.75 diopter cylindrical lenses, axis vertical, before both eyes).

C. Appraisals of visual efficiency (including figure 53---the relationship between the size of the threshold stimulus and visual efficiency expressed in percent; and figure 54---the influence of level of illumination upon visual acuity as illustrated by SNELLEN characters, expressed in terms of the Snellen fraction, or in terms of the A. M. A. scale of visual efficiency).

D. Visual deficiencies and the visibility of type (including table 52---visibility measurements of various diagnosed visual deficiencies and disorders, and the levels of illumination which are required in order to increase the visibility of 18-point type to equal that of 24-point type under 10 footcandles; table 53---visibilities obtained, with 18- and 24-point type illuminated to 10 footcandles, by subjects having visual deficiencies; and figure 55---juxtaposed scales indicating the visibility of various sizes of BODONI BOOK type under 10 footcandles, as determined for normal vision and by subjects possessing various ocular defects).

E. Education and vision (including figure 56---the age-grade characteristics of a group of school-children possessing visual deficiencies).

F. Basic eye-movements in reading (including figure 57---electromyograms showing the movements of the eyes as the fixation is rapidly shifted from left to right and vice versa, and up and down and vice versa; and figure 58---an electromyogram of basic eye-movements of an educated adult reader whose eye-movements in reading are characteristically erratic).

G. Actual eye-movements in reading.

H. Functional adaptation to near-vision (including figure 59---(a) relative visibility versus additional power in diopters, and (b) lead and lag in diopters versus fixational distance in diopters).

I. L-M sensitometric method of refraction.

XI. Reading performance.

A. General.

B. Speed and accuracy of visual performance.

C. Illumination and reading performance (including figure 60---relative measures of efficiency in reading).

D. Footcandle scale of effectiveness (including figure 61---illustrating the relationship between illumination and its influence upon visibility and ease of seeing).

E. Work-world tasks involving reading (including figure 62---the increase in production and the decrease in errors, respectively, which followed the installation of supplementary lighting units upon business machines).

F. Illumination and educational progress (including figure 63---the influence of improved lighting on educational age as determined with four well-balanced test-groups).

G. Visibility and ocular functions (including figure 64---the relative number of cases in the experimental and control rooms in which the refractive

changes from the beginning of the fifth to the close of the sixth grade were in the direction of less plus power).

H. Recommended levels of illumination (including table 54---conservative footcandle recommendations on a rational basis of the characteristics of the visual task and requirements of performance).

I. Visual relaxation and visual distractions (including figure 65---the relationship between rate of blinking while reading and the ratio of the brightness of the central to the surrounding field).

J. Ocular comfort and glare (including figure 66---some relationships between size and brightness of light-sources in the visual field as they affect the rate of involuntary blinking).

K. Auditory distractions.

L. Distractions within the central field (including table 55---number of blinks during 5-minute periods of reading under three lighting conditions, as determined by 5 observers).

M. Reading distance and its stability (including table 56---reading-distance in inches as observed on four occasions for 13 adult readers under 5, 10, and 20 footcandles, respectively).

XII. Psychophysiological effects associated with reading.

A. General.

B. Nervous muscular tension (including figure 67---showing the method of obtaining indications of nervous muscular tension while reading, and average pressures exerted upon the key while reading under 1, 10, and 100 footcandles, respectively; and figure 68---the relationships between indicated nervous muscular tension and level of illumination for each of 14 adult readers).

C. The heart-rate (including figure 69---the relationship between heart-rate and duration of reading for successive intervals of a test-period).

D. Rate of involuntary blinking (including figure 70---percent increase in rate of blinking after one hour of reading under levels of illumination of 1, 10, and 100 footcandles, respectively, as determined with 10 adult subjects).

E. Fatigue of the extrinsic eye-muscles (including figure 71---illustrating the extrinsic ocular muscles and presenting the decrease in tonicity of the lateral muscles after an hour of reading under 1 and 100 footcandles).

F. Pupillary changes (including figure 72---the relative area of the pupil at different periods of the 5-day work-week).

G. Various illuminants (including figure 73---the influence of illumination on important aspects of visual function and seeing).

H. An extension of Fechner's Law (sensation varies arithmetically as the stimulus is varied geometrically).

XIII. Specifications for optimum readability.

A. General (including figure 74---reading recommendations presented by the National Committee for the Prevention of Blindness).

B. Optimum size of type.

C. Optimum brightness.

D. Maximal brightness-contrast between ink and paper.

E. Non-glossy paper and ink.

F. Optimum type-face.

G. Clear-cut delineation of characters.

H. Brightness of surroundings.

I. Preventable glare.

J. Other distractions.

K. Correct eyeglasses.

L. Optimum leading.

M. Optimum line-length.

- N. Margins.
- O. Rest-periods.

XIV. Glossary of technical terms (including accommodation, alphabet length, arithmetic mean, behavioristic criteria, blinking, boldness of type, brightness, candle per square inch, candle-power, character count, contrast (brightness), convergence, diffuse reflection-factor, diopter, distant-vision, educational age, electromyogram, emmetropia, equivalent type-size, ergograph, extrinsic muscles, eye-movements, fixation, fixation-pause, footcandle, footcandle scale of effectiveness, footlambert (including figure 75---the relationships of three common units of brightness), fovea, geometric mean, glare, hyperopia, illumination, leading, legibility, millilambert, mimeograph, minute visual angle, myopia, near-vision, normal line of vision, normal vision, perceptual span, periphery of retina, photopic vision, pica, percent maximal visibility, point, presbyopia, probable error, pupillometer, readability, reading, reflection-factor, refractive error, regression, relative accommodation, relative footcandles, retinal sensitometer, relative visibility, snellen fraction, specular reflection-factor, speed of reading, systematic differences, threshold (visual), type-face, type-size, visibility, visibility meter, visual acuity, visual efficiency, and figure 76---a reduction of the 1932 American Medical Association Test-Chart).

XV. Specimens of type and typography.

- A. BODONI BOOK; in 3-, 4-, 6-, 8-, 10-, 12-, 14-, 18-, and 24-point; leaded 1, 2, and 4 points.
- B. BOOKMAN TYPE; in 10-point; leaded 3 points.
- C. CASLON OLD FACE; in 11-point; leaded 3 points.
- D. CENTURY EXPANDED; in 4-, 6-, 8-, and 10-point; leaded 1 point.
- E. EXCELSIOR; in 10-point; leaded 3 points.
- F. MEMPHIS LIGHT; in 10-point; leaded 2 points.
- G. MEMPHIS MEDIUM; in 10-point; leaded 2 and 3 points.
- H. MEMPHIS BOLD; in 10-point; leaded 2 points.
- I. MEMPHIS EXTRA BOLD; in 10-point; leaded 2 points.
- J. METROLITE; in 10-point; leaded 3 points.
- K. SCOTCH; in 10-point; leaded 3 points.
- L. TEXTYPE; in 6-, 8-, 10-, 11-, and 12-point; leaded 0, 1, 2, 3, and 6 points.
- M. Figure 77---a reproduction of ELITE and PICA typewriter faces scaled down to be equivalent in size to 10-point metal types, and leaded 2 points.

XVI. References (67).

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Mackworth, N. H.
Flying Personnel Research Committee (Gt. Brit.)
LEGIBILITY OF RAID BLOCK LETTERS AND NUMBERS
F. P. R. C. rept. no. 423(s), Apr 44, 18p.

Problem: "The aims of this investigation have been:- (a) to measure the legibility of the existing Sector Operations Room display numbers and letters when seen at different distances and viewing angles; and (b) to find whether there is any way of making these symbols more legible - first, without increasing the size, and secondly, with a slight increase in size." (p. 1)

Procedure: "The following types of display letters and numbers were compared;- (a) 'PRESENT SECTOR' RAID BLOCK equipment - black characters on an orange - yellow background, the colour code for hostile aircraft. (b) 'NEW SECTOR' equipment - modified black characters on a light lemon - yellow background, the suggested new display. (c) 'PRESENT GCI' equipment - black characters somewhat elongated on an orange - yellow background. (d) 'NEW SECTOR (GCI SIZE)' equipment - modified black characters enlarged to the present size on a light lemon - yellow background. . . (e) Red numbers on a white background - the existing sector display for friendly aircraft. The numbers and letters were automatically exposed (for 1.62 seconds each every 1-3/4 seconds) one at a time and each (of 212 W. A. A. F.) subjects read a complete set from . . . 25 . . ., 30 . . ., 35 . . . and 40 feet . . . . Each set consisted of a jumbled series of the numbers 0 - 9 and the letters A - Z with the exception of I, L, O and T. . . shown at right angles . . . and also at oblique presentations. . . The fluorescent . . . illumination on the display was 10 foot candles." (p. 2)

Result: "RESULTS have been considered under five main headings:- . . . (p. 2)

1. "Reduced Incidence of errors when only contrast and design were improved. . . (W)hen the display (was) set square to the line of sight the viewing distance (was of) great importance. Neither the PRESENT SECTOR nor the NEW SECTOR (could) be read accurately from distances greater than 25 feet by people with good eyesight; increasing the . . . distance to 30 feet more than double(d) the incidence of errors. . . (The) advantage in favour of the NEW SECTOR display was also found at oblique viewing angles. . . (I)n the case of the NEW SECTOR, alteration in the viewing angle without any other change can lead to as much as a sixteen fold increase in errors at this particular distance. . . (p. 3-4)
2. "The Effects of a Slight Increase in the Size of the Characters plus Improved Contrast and Design. . . (A)t the 25 feet - 30 feet distances it is not real solution (sic) of the problem simply to increase the size of the display and replace the PRESENT SECTOR by the PRESENT GCI letters and numbers . . ., provided the display is set squarely to the line of sight. . . At these two distances and with the 90 (degree) viewing angle the NEW SECTOR display with improved contrast and design seems to give a better result than the larger PRESENT GCI display . . . . This difference is not so definite as it looks because . . . the NEW SECTOR subjects had rather better vision. One can however safely say that there is no significant difference in visibility between NEW SECTOR and PRESENT GCI displays under these conditions even though the latter takes up more space. . . At all four distances the effect of improved contrast and design is quite clearly confirmed (with all differences statistically significant in favor of the GCI SIZE) by comparing the PRESENT GCI with that of the NEW SECTOR (GCI SIZE). . . Statistical tests show no real difference between the results given by the NEW SECTOR (SAME SIZE) and those of NEW SECTOR (GCI SIZE) provided the viewing angle is 90 (degrees) and the viewing distance (is) 25 . . . or 30 feet. . . This last finding has been checked with another set of results obtained from test series composed entirely of numbers. . . compari(ng) . . . PRESENT SECTOR . . . and

. . . PRESENT GCI numbers first set squarely to the line of sight and then . . . where the viewing angle was 45 (degrees). . . Once again the slightly larger size (was) of real value when the viewing conditions (were) difficult on account of . . . distance - or when the display (was) set obliquely . . . The PRESENT SECTOR display (gave) 13. 5 (percent) errors with numbers alone and 19. 2 (percent) errors when both letters and numbers (were) shown in the same test series - on averaging all four distances and taking only the 90 (percent) viewing angle. . . (U)nder similar viewing conditions the PRESENT GCI shows a much larger difference: 3. 2 (percent) for numbers alone and 12. 6 (percent) for letters and numbers together. . . (p. 4-5)

3. "Black on Yellow Display compared with Red on White Display. . . PRESENT SECTOR numbers printed in read . . . on a white background. . . averaged 18. 2 (percent) errors when set squarely to the line of sight. This was significantly worse than the 13. 5 (percent) errors made by the same . . . subjects with identical numbers printed in black on an orange yellow background. " (p. 5) The following shows a "(t)able of the reflection factors of the materials used in these experiments. The lower contrast index explains the higher error incidence with the red on white display. ". . : (p. 5)

| Material | Reflection Factor (percent) | Percentage Contrast | Average (percent) Error Incidence |
|---|---|---|---|
| PRESENT SECTOR: | | | |
| Red Lettering | 19 | | |
| White Background | 73 | 74 | 18. 2 |
| PRESENT SECTOR: | | | |
| Black Lettering | 4 | | |
| Orange Yellow | | | |
| Background | 48 | 91 | 13. 5 |
| NEW SECTOR: | | | |
| Black Lettering | 4 | | not comparable |
| Lemon Yellow | | | as design changes |
| Background | 60 | 93 | were also made |

(above from p. 5)

Note: Percentage contrast or contrast index =

$$\frac{\text{reflection factor of background - reflection factor of lettering}}{\text{reflection factor of background}} \quad X \quad 100$$

4. Nature of the errors. "There (was) a wide range in the visibility of the different characters. . . The improved contrast and design of the NEW SECTOR (SAME SIZE) display reduce(d) the incidence of errors in 26 out of the 32 characters in spite of the fact that the subjects were all very practised at reading the PRESENT SECTOR display. . . The factor of contrast (was) probably more important than the design changes. . . There was a tendency . . . to read numbers as letters, possibly because letters were in the majority and the subjects would therefore be more likely to expect a letter . . . But the PRESENT SECTOR (numbers only) analysis shows that this is not the only cause . . . . Other possible reasons are that the numbers have been allotted less space than the letters - and perhaps also that the letters tend to make more use of straight lines which are relatively easier to see than curved lines. " (p. B1)

5. Relation of the results to the vision gradings of the subjects. "By considering people with normal vision instead of those with exceptional eyesight and by adding only 15 feet to the viewing distance . . . turn(ed) absolute success with the PRESENT SECTOR display into complete failure - an increase from 1. 4 (percent) . . . to 100 (percent) errors . . . (T)his is not an argument for a more rigorous

selection of plotters. On the contrary, small improvements . . . (should) bring the work within the capabilities of the ordinary person. . . (F)or example, . . . the NEW SECTOR (SAME SIZE) display with its improved contrast and design is of greater value to people with normal eyesight than to those with exceptional vision. . . An attempt was made to see whether the . . . results . . . were related . . . to the length of . . . experience in Operations rooms. At first a slight . . . relationship was found . . . It seemed likely however that some at least (of) this . . . might be due to the factor of age . . . A partial correlation . . . with the influence of age removed. . . reversed the previous finding and there was now no relation . . . between vision test errors and length of . . . experience. . . In other words . . . , there (was) no connection . . . that (could) not be accounted for by . . . age. . . Another analysis . . . showed . . . no difference . . . between . . . more than one year . . . and . . . one year or less - nor was there any difference between two years or longer and . . . less than two years . . . ."(p. C2-C3) From this, "(t)wo conclusions are possible, either (a) Personnel are quick at noticing any deterioration in . . . acuity and report it . . . so that . . . eyesight is maintained with . . . spectacles; or (b) Work in Ops. rooms has no permanent effect on eyesight as measured by the standard visual acuity test." (p. C3)

From all these results, the following conclusions were drawn:

1. "The NEW SECTOR (SAME SIZE) display letters and numbers . . . should be used . . . instead of the PRESENT SECTOR display when the viewing distance is not more than 25 feet. No alteration in the size of the display is needed but slight changes in the design of the type and a small improvement in the contrast between display and background will cut the error incidence to half its present value . . . . (p. 6)
2. "(I)n . . . circumstances . . . (where) moving the table closer to the dias is not going to reduce the viewing distance to 25 feet. . . there is a very definite advantage in using the NEW SECTOR (GCI SIZE) display. This slight increase in size plus the improved contrast and design cuts down the errors at . . . 35 feet . . . to less than one-third of its existing value. (p. 7)
3. "When tellers are having some difficulty in seeing the display they are more likely to guess than admit that they are unable to see properly. (p. 7)
4. "(I)f one takes the factor of age into account a standard eye test fails to show any difference between the working eyesight of people who have been in Ops. rooms for one year and those who have been there for several . . . ." (p. 7)

* * *

3318 Mackworth-1952

Mackworth, N. H.
Flying Personnel Research Committee (Gt. Brit.)
SOME NUMBER-LEGIBILITY TESTS IN A MOCK-UP CONTROL ROOM
Rept. no. F. P. R. C. 785, Mar 52, 2p., 1 ref.
TIP-71 616

Problem: "Tests were made of the legibility of raid block displays . . . of a proposed new (Royal Air Force) Control Room. The purpose . . . was to test the suggested arrangements for this Control Room while it was still in the early mock-up stages of canvas and scaffolding." (p. 1)

Procedure: Six WRAF tellers, 17-18 years of age, and with normal vision, viewed "(t)en RAID BLOCKS . . . each with a three-figure index number followed by an identification letter, the strength and also the height designation. These plaques were fastened to a (flat) display table . . . Five different telling positions were tried . . . ." (p. 1) The

following table gives the viewing distance and angle for each position:

| | 2nd floor | 1st floor | 1st floor | teller dias | teller dias |
|---|---|---|---|---|---|
| viewing distance | 35 feet | 30 feet | 24 feet | 19 feet | 27 feet |
| viewing angle | 70 degrees | 50 degrees | 35 degrees | 25 degrees | 20 degrees |

(above from p. 1)

Result: The following error scores and percentages were derived for the above five positions:

| | 2nd floor | 1st floor | 1st floor | teller dias | teller dias |
|---|---|---|---|---|---|
| error score | 37/60 | 41/60 | 1/60 | 18/60 | 59/60 |
| error percent | 63% | 68% | 2% | 13% | 93% |

(above from p. 1)

"The . . . results showed that the placing of . . . tellers in the room would make all the difference between perfect (sic) visibility and a situation in which very nearly all the identification readings would be quite wrong." (p. 1) Specifically, "(i)f tellers have to work from some . . . central dias, there is a real need to try to avoid the slight loss of accuracy due to the resulting slant view by adopting the suggested shape changes to identification numbers mentioned in 'Planned Seeing'.". . (F. C. Bartlett and N. H. Mackworth. Planned Seeing: Psychological Experiments. Air Publication 3139B, 76. HMSO, 1950). (p. 2) Also, "(s)ize limitations to the display make it inevitable that tellers will work under borderline seeing conditions. Reduction of visual acuity by even one line on the eye chart is known to give a very considerable increase in errors with this display (Fig. 18 op. cit.) It therefore seems reasonable to suggest that tellers should have normal binocular vision . . . ." (p. 2)

* * *

3374 Mead-1954

Mead, Leonard C.
Tufts Coll., Medford, Mass.
THE TYPOGRAPHY OF TOMORROW
Bookbinding and Book Production, 59:3
(March 1954) 72-74

Problem: "Is it possible in some way to 'flag the eyes' of a skilled reader so that they may more quickly and more accurately catch the significant parts of a manuscript and thus improve even a skilled reader's comprehension per unit time? Historically the development of print has been in the direction of sharper type, reduction of letter size, and . . . simplicity of styling." (p. 72) Since this seems to have reached a plateau, further development would seem to be in the directions of either format changes (possibly meaning less complex programs for such developments as the Photon) and/or basic changes in the number and direction of strokes in characters.

Procedure: This paper is based upon the work of Mead, Dearborn, and Johnston, in which college students were given (1) a conventional reading test scored on the basis of questions on passages read, (2) other reading passages in which they were required to indicate those words which they would stress in reading aloud, and (3) reading tests in which typographical emphasis had been placed on words and/or clauses and sentences. The following methods were used for giving typographical emphasis: color, varying letter heights, contrasting boldnesses, putting key words in upper case, single line clauses (with line justification on the center), separation of sentences within a paragraph, two-column formatting, and accent marks over key words. Similar methods have been used by strip cartoonists for many years, as for example in "Dick Tracy" (Chicago Tribune), "Orphan

Annie" (News Syndicate Co., Inc.), and "Li'l Abner" (United Feature Syndicate Inc.). However, radical changes, such as simplified spelling also found in cartoons, were not attempted here.

Result: Reader resistance to innovation and habit change indicated that acceptance appeared to be more related to the character, rather than the amount, of modification, and that modifications must be immediately acceptable to a majority of competent readers. However, the following results seem to be pertinent:

1. Placing "alternate clauses on slightly different levels provoked . . . uncomplimentary comments." (p. 73) Yet, "surprisingly, . . . 40 (percent) . . . preferred this . . . ." (p. 73)
2. 50 percent preferred light and dark clause alternation and the two-column format.
3. Word stressing, when done extensively, resulted in such clumsiness that the reader finally tended to overlook all stresses. However, suitable word stress improved comprehension per unit time.
4. Better comprehension resulted from coincidence of author and subject stresses.
5. Irregularities in eye movement were the result, rather than the cause, of poor comprehension.
6. Reasonable modifications in typography were accepted, and some were preferred, "particularly (by) those . . . with estimated high I. Q.'s." (p. 74)

Generally, to be of benefit, changes in conventional formats should improve the reader's understanding rather than be merely an arrangement to move his eyes in a particular fashion.

* * *

2207 Mecherikoff-1959

Mecherikoff, M. and Horton, D. L.
Westmont Coll., Santa Barbara, Calif. and
Minnesota U., Minneapolis

PREFERENCES FOR LETTERS OF THE ALPHABET

Journal of Applied Psychology, 43:2
(April 1959) 114-116

Problem: "(D)etermine whether . . . consistent preferences for letters of the alphabet exist . . ., and . . . identify pairs of letters which have equal preference value . . . ." (p. 116)

Procedure: "(S)even (capital) letters (G, K, N, P, S, T, and V---chosen on the basis of two preliminary studies as having the least likelihood of being different---in sound and in appearance of the capital---from each other in appeal) were presented pairwise in all (21) possible combinations (mimeographed onto sheets of 8-1/2 by 5-1/2 inch paper) to 182 college students (of mixed sexes) . . . ." (p. 116) The subjects' "task was to . . . circle the letter (in each pair) he preferred." (p. 114) Preferences for (a) the beginning vs. end of the list, (b) the middle vs. extremes of the list, or (c) the right or left member of a pair, were accounted for by the preparation of eight forms of the basic list.

Result: The following three major conclusions were drawn:

1. "The following pairs showed a preference for the letter listed first at significance level indicated:

   1% level: SK, SG, SP, ST, GK

   5% level: PG, NK, NG, SN, SV, TK

2. "The following pairs show no preference for either letter, with $.50 \pm .05$ as the tolerated limits (described by Walker and Lev, 1953):

   Power 85%: GT and VP

   Power 75%: TV and VK

3. "There do not appear to be any consistent position preferences or sex differences, except that the letter K is significantly preferred by more women than men." (p. 116) The authors state that those studies "(c)losest to the present problem are studies of number preferences, e.g., Yule (see Chapanis-1949, elsewhere in this volume; and G.V. Yule, On reading a scale, Journal of the Royal Statistical Society, v. 90 (1927) 570-587) and a study by Forer (B.R. Forer, A study of consonant preferences, Psychological Bulletin, v. 37 (1940) 589---an abstract) which deals with preferences for sounds of consonants." (p. 114)

* * *

3275 Melville-1957

Melville, Joseph R.
Florida U., Gainesville
WORD-LENGTH AS A FACTOR IN DIFFERENTIAL RECOGNITION
American Journal of Psychology, 70:2 (June 1957)
316-318, 6 refs.

Problem: Based on the work of Forgays, Mishkin and Forgays, Orbach, and Huey,* "(t)he purpose . . . is to . . . tes(t) . . . the relative importance of the first letters of words (in word recognition). . . (and determine whether) seven-letter words would . . . show significantly greater differential recognition than three-letter words." (p. 317)

Procedure: Eighty-one subjects (60 men and 21 women) viewed 10 three-letter and 10 seven-letter words. "A Keystone Overhead Tachistoscope was so placed that the projected image of tall letters in PICA type averaged 2 (centimeters) in height. . . A fixed head-rest placed (the subjects') eyes 2 (meters) from a white screen. . . Words projected on the screen were centered either 10.6 (centimeters) to the right or . . . to the left of the fixation-point. . . Exposure-times ranged from 10 to 100 (milliseconds), and monocular and binocular vision were counterbalanced." (p. 317)

Result: "Analysis of variance indicated a significant (1/10 percent level of confidence) interaction between word-length . . . and word-position . . . ." (p. 318) Seven-letter words to the right were better than three-letter words to the left or right, which were also better than seven-letter words to the left. There was no "significant differential recognition . . . for three-letter words. (However, t)he null hypothesis (whether seven-letter words would show significantly greater differential recognition than three-letter words) was rejected at the 1/10 (percent) level . . . (Thus,) Huey's argument (concerning the differential recognition of words as a function of retinal focus---the doctrine of equipotentiality) was supported. . . (and) the doctrine need not be rejected on the basis of previous studies . . . ." (p. 318)

*D.G. Forgays, The development of differential word-recognition, Journal of Experimental Psychology, v. 45 (1953) 165-168; Mortimer Mishkin and D.G. Forgays, Word-recognition as a function of retinal locus, Journal of Experimental Psychology, v. 43 (1952) 43-48; Jacob Orbach, Retinal locus as a factor in the recognition of visually perceived words, American Journal of Psychology, v. 65 (1952) 555-562; and E.B. Huey, The Psychology and Pedagogy of Reading, 1908, 96-99, of which a subsequent edition has been abstracted herein as Huey-1916.

* * *

2189 Moore-1958

Moore, Leonard C. and Nida, Paul M.
Technical Development Center, Federal Aviation
Agency, Indianapolis, Ind.
AN ANALYSIS OF LETTERING STYLES FOR AN IMPROVED
RASTER-TYPE DATA DISPLAY
Technical development rept. no. 378, Dec 58, 10 p.

Problem: Analyze a study that developed a set of minimum-size, alpha-numeric characters that would be legible regardless of orientation when presented on a raster-type, pictorial, air-traffic control display (Spanrad).

Procedure: In analyzing and continuing the work done by Rowland and Cornog (Courtney and Company, DDC document number AD-203 318), the evaluating group viewed various commercially available type faces and the specially designed COURTNEY face on a 27-inch, 625-line, cathode ray tube (CRT) screen. The characteristics of the television equipment considered were (1) number of raster lines, (2) camera resolution, (3) lighting, and some others not specified. Assuming omni-directionality of character and/or observer position, the characteristics of the faces considered were (1) minimum size, (2) acceptable style, (3) form and direction of contrast, (4) illumination, and (5) vertical and horizontal spacing.

Result: After elimination of the commercial faces "since they obviously were unacceptable," (p. 3) the COURTNEY face was accepted as a basis for CRT and "marker data" character display design criteria. From its design, the following recommendations were derived (assuming numerals and upper case letters of equivalent height):

1. use an 875 vs. 625 raster line system to reduce character height by 1/3 and still retain legibility at the viewing distance of four feet,
2. use "bold" (stroke-width equal to 20-25 percent of height), "expanded" (width equal to approximately 75 percent of height) characters,
3. use maximum intense white on dead black contrast, except for the use of black on light red on the marker board when it is not desired to display the characters on the CRT screen,
4. even though a 5-line character height is considered the theoretical minimum, a 9- to 10-line height seems a more practicable standard,
5. use horizontal spacing equal to 10-20 percent of character height and vertical spacing minimum of three raster lines, and
6. within limits, use brighter illumination for greater legibility.

Also, further study was indicated as desirable for (1) the reproduction and arranging of the selected character set, (2) illumination levels, and (3) color combinations.

* * *

3321 Moore-1962

Moore, R. L.
TRAFFIC SIGN DESIGN
Traffic Engineering and Control, 3:11 (March 1962)
685-688, 1 ref.

Problem: Discuss some of the factors involved in meeting the following principles of highway sign design:

1. "The driver's act of reading the sign should not require him to slow down or distract his attention unduly from the task of driving safely in the prevailing traffic conditions.
2. "A traffic sign should be perceived and understood by a driver travelling at the average speed of traffic on the road sufficiently early for him to take any necessary action with safety.

3. "The sign should fulfill the above conditions by night and day." (p. 685)

Procedure: Theoretical assumptions lead to the conclusion "that letter height h should be . . .

$$(N - 6) \frac{V}{100} - \frac{S}{10} \text{ inches . . .}$$

"where N is the number of names on the sign.
V is the velocity of the vehicle in mile(s per hour),
S is the distance of the sign from the vehicle's path in (feet); and drivers are assumed to have the . . . ability to read signs at 50 (feet per inch) of letter height. . .

"To test this, the following signs (were) compared in terms of reading distance:

(a) "The conventional panel layout.
(b) "The 'Continental' type with a map of the junction with place names opposite arrowheads.
(c) "Signs made with a stack of names one above the other with arrows indicating the direction. . .

"(O)bservers seated in a vehicle driven at 50 (miles per hour) were asked to report the instant at which they had identified a given (sign) and knew which direction (and/or action) to take." (p. 685-686)

Result: "The following represents the score sheet . . .; the 'best' sign is that which is interpreted at the greatest range.

"(a) Recognition of sign type (warning, mandatory or informatory):

| | British | Continental | American |
|---|---|---|---|
| mean | feet | feet | feet |
| values | 570 | 640 | 700 |

"(b) Identification of the particular sign:

| | British | Continental | American |
|---|---|---|---|
| mean | feet | feet | feet |
| values | 210 | 240 | 200 |

"Notable exceptions to this general pattern were:

1. "Halt signs, where the American sign was best with an identification distance of 405 (feet).
2. "Yield/Slow signs where again the American sign is best with a distance of 615 (feet).
3. "No Waiting and Roundabout signs which came out best on the British system with distances of 270 and 230 (feet) respectively." (p. 687)

The following general conclusions concerning sign types were given:

1. "(A)cceptable sizes of lettering . . . may be derived from the formula shown above.
2. "At simple cross-roads at right angles a stack type of sign with arrows is satisfactory.
3. "At junctions with more unusual layout or more than two roads a map type of layout without panels is advisable.
4. "Large direction signs should have dark backgrounds and light letters; small signs should have light-coloured backgrounds (and dark letters). . .
5. "Signs in roads where there is street lighting require illumination with lamps of better design than those in use . . . . On all other roads the use of reflective sheeting or other means of reflectorization if equal efficiency is required." (p. 687)

Concerning sign lettering, "it was found that there was practically no difference between good lower-case sans-serif lettering, unserifed upper-case and upper-case with serifs. If anything, the upper-case with serifs had a small (3 percent) advantage on legibility distance. . . One advantage of lower-case may . . . be . . . (that) a sign with lower-case letters is narrower but taller than an equal area upper-case sign. Where there is

restriction on the width of a sign, . . . there are clear advantages in using lower-case letters. . . (Further, it is) suggested that there are probably advantages in using both upper- and lower-case letters for different purposes .". . (p. 686) such as the use of upper-case for all mandatory and warning signs. A more complete discussion of color in signs than is indicated here. Also discussed in some depth are the economics of sign design and placement.

* * *

3327 Murrell-1952

Murrell, K. F. H.
THE DESIGN OF INSTRUMENT SCALES
Instrument Practice, 6:4 (February 1952) 225-232, 22 refs.

Purpose: "It is not perhaps generally realized that bad scale numbering is a factor which contributes much to the inaccuracy of scale reading . . . It is the purpose of this paper to summarize that part of the research which deals with the design of the dial face and its effect on reading accuracy." (p. 225)

Extract: "(F)or black on white the ratio of the height/stroke width should be 6 (to) 1, and for white on black 10 (to) 1. Thick and thin strokes should never be used. . . (The) height/ width (ratio) . . . shows a difference of opinion. The U. S. Army/Navy standard is 3 (to) 2, while Kuntz and Sleight propose a proportion in which the letters are wider than they are tall, 0.77 (to) 1. The general conclusion would seem to be that no advantage is to be gained in legibility in making figures tall and thin and that the space between digits should be approximately half the width of the digit. . . The shape of the digits has a very marked effect on their legibility and the order of legibility appears to be 1, 7, 0, 4, 3, 2, 9, 6, 5, and 8. . . Berger arrived at the following results:

1. "The angle at the base of 2 and 7 and the tails on the 9 and 6 should be 45 (degrees).
2. "The top of the 4 should be closed.
3. "The bar on 5 should go half-way across the full width.

"Based on these rules he designed a series of square figures. Bartlett and Mackworth have also studied the legibility of figures and numerals and their design is shown . . . (I)n general it may be said that 3/8-(inch) figures should be used on a scale 5 (inches) in diameter and other sizes pro rata. Sewig recommends that parallel figures should normally be used but when the dial is very crowded radial figures should be used. . . The best results are obtained when there is a maximum contrast between the numerals and the dial face. In general the use of black figures on white is to be recommended except when dark adaptation is required." (p. 230)

* * *

2188 Murrell-1958

Murrell, K. F. H., Laurie, W. D. and McCarthy, C.
Bristol U. (Gt. Brit.)
THE RELATIONSHIP BETWEEN DIAL SIZE, READING DISTANCE AND READING ACCURACY
Ergonomics, 1:2 (February 1958) 182-190

Problem: Determine the effect of variations in dial size and reading distance and interactions between them on the accuracy of reading circular dials. "(T)he major finding(s) (of previous work indicate that) . . . errors decrease with increasing space between scale marks, very rapidly until an interval of 0.25 (inches) is reached, then gradually to a minimum at 0.50 (inches). From this it is concluded that for maximum reading accuracy (at a 30-inch reading distance) the width of the space between marks on

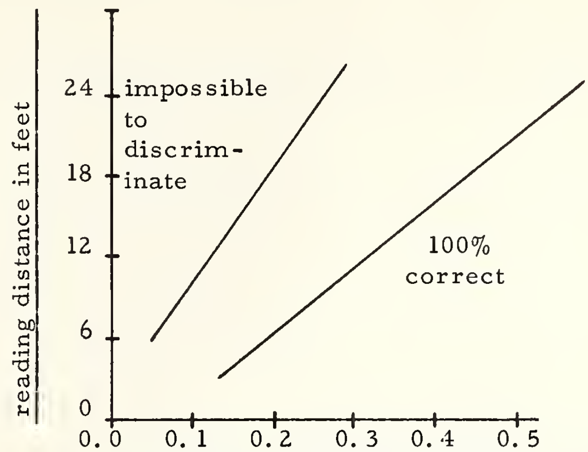
any scale should fall between these values." (p. 182) Since actual practice does not bear out a direct proportionality between dial size and reading distance, "(t)he present experiment was undertaken in order to obtain further information on the optimum size of dial to be used at different reading distances." (p. 183) Determine also if there is a correlation between dial reading and the legibility of numerals used thereon.

Procedure: "The method used was that developed by Kappauf, Smith and Bray (1947) which consisted in mounting 12 dials on a board and exposing them to the subject who was required to read indicated values at his own pace, timing being made from the end of the first reading to the end of the eleventh reading." (p. 183) The dials were of 2-, 3-, 4-, 6-, and 8-inch nominal diameter. Scale diameters were 5/6 of these. Dial figures were of the MACKWORTH design in black on a white dial face. Each dial contained 200 units on a 270-degree scale with 0 at 3 o'clock. Graduations were numbered in twenties and sub-divided into tens (a preliminary experiment showed that the 20 by 10 was read faster and with at least as high accuracy as a 20 by 5, and was read both faster and more accurately than a 50 by 10). Brightness at the dial face was 30 foot-lamberts. A buff-colored, hand-drawn blind was used in front of the dial board when it was not being viewed. Dials were mounted on a gray board that had a reflection factor of 60 (percent). Pointer settings on the dials were random. Subjects' eyes were situated at approximately 2-1/2, 6, 9, 12, 18, and 24 feet from the dials. The order of dial readings was randomized. Each subject participated in 14 of a possible total of 30 viewing interactions (dial size by distance). Subjects were six Naval Chief Petty Officers (four had 6/6 and the two others had 6/12 vision) who had not had dial-reading experience in the course of their naval duties. Accuracy and speed were the test criteria. In order to test a possible correlation between the accuracy of dial reading and the legibility of numerals on the dials, the experimenters "prepared a series of six cards each with five rows of 10 numerals, each row corresponding to the size of the numerals in each of the five dial sizes. Each subject read one of the cards at each of the six distances and the whole sequence was repeated once." (p. 189)

Result: The scores utilized were those taken after a learning effect had levelled off. From these, the following results were seen:

1. accuracy v. dial size - "(I)t is the 'apparent size' . . . which determines the accuracy . . . (for instance a 3 inch dial at 6 feet and a 6 inch at 12 feet are . . . the same 'apparent size') . . . (E)xpressing this . . . was obtained by using the angle (in minutes) subtended at the eye . . . ." (p. 187)
2. accuracy and speed v. dial size - "(T)here (was) an increase in the percentage of correct readings and a decrease in reading time with increase of apparent size until a critical point (was) reached, after which there (was) little or no improvement. . . For all ('called intervals') this critical point was reached at about 98 per cent accuracy except for the . . . interval of 1 unit when it was reached at 80 per cent. . . With the called interval of 1 unit the points representing the viewing distance of 2-1/2 (feet) did not fall in line with those representing the seats further away. This suggests that when very great accuracy of judgment is required the proportional relationship between size and distance does not hold good for short distances of about 30 (inches) . . . Kappauf and Smith's results (when plotted on the same basis) behave in much the same way as do ours although their curves reach the critical points at higher values of apparent size. This may be due to the greater amount of practice put in by our subjects." (p. 187-189)
3. performance v. dial size - The critical point for accuracy was reached at an "apparent size of called space (p. 186) (the physical size of the interval into which the scale space, i.e., the physical size of the interval between two scale marks, has to be sub-divided 'by eye'---interpolation)" (p. 184) of about 21 minutes of arc (visual angle). The critical point for speed was reached at about 23 minutes of arc.
4. performance v. visual acuity - "(S)ubjects with 6/12 eyesight gave . . . (e)quivalent performance . . . at a larger apparent size, representing a decrease of reading distance of about one-fifth." (p. 188)

5. performance v. numeral size - "It is evident that when an observer becomes 'practised' he does not need to be able to read the numerals in order to find his way about." (p. 189) Specifically, the following chart shows the "(r)elationship of numerical height and reading distance": (p. 189)




(above chart from p. 189)

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2673 Nahinsky-1956

Nahinsky, Irwin D.
Minnesota U., Minneapolis

THE INFLUENCE OF CERTAIN TYPOGRAPHICAL ARRANGEMENTS UPON SPAN OF VISUAL COMPREHENSION

Journal of Applied Psychology, 40:1 (February 1956) 37-39

Problem: "(C)ompare the span of visual comprehension for the square span, the spaced unit, and the conventional typographical arrangement by presenting tachistoscopically sentences printed in all three styles." (p. 37)

Procedure: The following three sentences illustrate the conventional, spaced-unit, and square-span typographies, respectively:

The street was not well paved .

Do not leave his glove here .

The two boys saw
the car pass .

Thirty college student subjects (age 18 to 39) viewed these arrangements in the Dodge mirror tachistoscope for an exposure period of 100 milliseconds each. "Each (subject) was given a point for each word correctly reported irrespective of whether the order was correct." (p. 38)

Result: "The square-span style yielded comprehension spans significantly superior to both of the other two styles investigated. . . The other two styles yielded comprehension spans not significantly different from each other. . . All the styles showed a high degree of interrelationship for all the subjects. . . The data indicate that the greater utilization of the vertical visual span was the factor that yielded superior comprehension scores for the square-span style. . . The square span style used in books and advertising might lead to increased reading and comprehension speed. This warrants further investigation.". ., (p. 39) especially since the author indicates that, because of the evidence shown (20 subjects better under square-span, 1 equally well under square-span and conventional, and 9 better under conventional layout), "great caution should be exercised in accepting the square-span style as being unequivocally superior . . . ." (p. 38)

* * *

3302 Neisser-1960

Neisser, Ulric and Weene, Paul
Brandeis U., Waltham, Mass.

A NOTE ON HUMAN RECOGNITION OF HAND-PRINTED CHARACTERS

Information and Control, 3:2 (June 1960) 191-196
Contract AF 19(604)-5200

Problem: With a view toward "the development of machines that can read . . . HAND-PRINTED material . . ., (p. 191) determine the relative and total legibility of a set of HAND-PRINTED alpha-numeric characters.

Procedure: Nine subjects (college students or graduates that were aware of the purpose of the experiment, i. e. the development of an accuracy criterion for HAND-PRINTED character recognition machines) each viewed 18 individual photographs of HAND-PRINTED, upper-case,

alpha-numeric character samples, A-Z and 0-9 (selected from a pool obtained at the Lincoln Laboratory). Each photograph showed a blow-up of a black-on-white character, inscribed within a 2-3/4 X 2-3/4 inch square. The stimuli were viewed in random order at 2-3 yards distance with the subject performing a cross-out task, on a record sheet, of his best guess for each character. Accuracy was the test criterion, since this human accuracy would seem to "serve as (a) standar(d) for the accuracy of mechanical devices . . . ." (p. 191)

Result: Results were presented in a confusion table. From this, the following conclusions were drawn:

1. O (oh) was not distinguished from 0 (zero) at all.
2. I (eye) was distinguished from 1 (one) only poorly.
3. A, H, K, M, R, Z, 3, and 8 were recognized without error.
4. T, U, V, Y, and 2 presented the most difficulty. However, even for these, correct recognitions predominated.
5. Overall mean error for the nine subjects was 4.1 percent.
6. "A particularly meaningful minimum rate (was) the proportion of modal errors, 3.2 (percent). In a sense, this represent(ed) the degree of sheer illegibility in these exemplars of HANDPRINTED characters." (p. 196)

Overall, "individual accuracies ranged from 94.9 . . . to 96.5 (percent), and even (the) pooled best guess was right only 96.8 (percent) of the time .". ., (p. 191) as shown by modal errors, above.

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3276 North-1951

North, Alvin J., and Jenkins, L. B.

Southern Methodist U., Dallas, Tex.

READING SPEED AND COMPREHENSION AS A FUNCTION OF TYPOGRAPHY

Journal of Applied Psychology, 35:4 (August 1951) 225-228, 6 refs.

Problem: Compare square span, spaced unit, and standard typographic arrangements by means of reading speed, comprehension, and accuracy.

Procedure: One hundred and eighty university social science freshmen read three articles from a popular magazine, each of which was printed in standard, square span, and spaced unit typography. Each typographic arrangement was presented to one group of 60 subjects. The following are examples of the two new arrangements:

| | | |
|---|---|---|
| This is | of the | style of |
| an example | square span | presentation |

This is an example          of the spaced unit          style
of presentation

"In breaking the material into units . . . , an attempt was made to group words into thought units." (p. 225) The first two articles were for practice and the third was tested for comprehension and accuracy (using an objective test), and reading speed. The test article had, according to the revised Flesch formula, a "reading ease" score of 36.9 and a "human interest" score of 11.6, indicating a moderately difficult style. The experimental design was factorial. A secondary consideration in the experiment was to determine the differential effects of practice.

Result: "In terms of reading speed and comprehension . . . , spaced unit was superior (statistical significance at the five percent level of confidence) to square span or standard typography. This advantage . . . was not accompanied by a loss in accuracy of retention. No differences attributable to the two limited degrees of practice (tested) were found. . . The hypothesis is offered that spaced unit . . . provid(es) auxiliary cues for the organization of thought. . . (T)he spaced unit style . . . may have immediate practical application, perhaps in academic and military instructional materials. . . Further research . . . is recommended." (p. 228)

* * *

2190 OptRead-1961

OPTICAL READING (MACHINES THAT READ PRINT AND AUTOMATICALLY CONVERT THE INFORMATION OBTAINED INTO A FORM SUITABLE FOR DIRECT INPUT INTO DATA PROCESSING SYSTEMS)
Data Processing, 3:2 (April-June 1961) 68-77

Abstract: The author discusses the optical print-reading machines and associated equipment produced by the Farrington Manufacturing Company (formerly Intelligent Machines Research Corporation). Reference to this article (and also Utman-1963) is made because many optical reading machines are currently in service in this and other countries in applications such as "keeping the records of a book club . . . (, ) preparing technical abstracts. . . (and) credit sale accounting . . . ." (p. 68) The application of these machines to commerce presents the unique problem of requiring a type font that is designed for recognition not only by the reading machines (whether they be optical or magnetic), but also by human beings for the purposes of verification, emergency manual operations, etc. Following a general introduction describing Farrington's major equipment (transaction recorders and optical readers) and its current applications, the article describes the SELFCHEK type font, the operation of transaction recorders, the scanning and decoding operation, equipment that will read type fonts other than SELFCHEK, and future applications and research. Delineation of the transactions and operations involved in a typical credit sale and its accounting, is interspersed throughout the discussion. It is pointed out that "(t)he major differences that exist between the various machines are confined to the type of document from which information can be read and the manner in which it is subsequently handled. . . In conformity with . . . other codes designed for machine reading, the figures (numerals) . . . are of a special design(, a) fount known as SELFCHEK . . . developed for (the) purpose (of optical machine-reading) by Farrington. . . Each SELFCHEK figure is formed by utilizing the appropriate strokes of a seven-line basic pattern. Three of the lines are horizontal and four vertical (⊟). Each long vertical may be treated as two separate lines. This basic pattern is modified slightly where necessary so that the resulting outline conforms more closely with the accepted appearance of a figure. For instance, indentations are made in the basic pattern in the region of the central horizontal stroke so that the resulting figure 8 more nearly resembles its conventional ARABIC counterpart. This particular modification also serves to increase the contrast between the figures 8 and 0." (p. 69-70) In a plastic credit card embossing application "the SELFCHEK figures are approximately 0. 17 inch high and are spaced horizontally at seven to the inch. The figures are printed (on transaction cards) in an area approximately 2. 5 inches long by 0. 4 inch deep. Margins 1/16 and 3/8 of an inch wide are maintained between the printed line and the top and left-hand edges of the documents respectively. . . (p. 70) (T)he reversed carbon impression (on the back of an imprinted card) is chosen (for reading by the optical scanner) in preference to the ink impression (because) the density of the inked image tends to vary as the ink dries out on the roller (of the transaction recorder). In contrast, the density of the carbon impression (from a two sided carbon behind the card) remains consistent." (p. 72) Potential applications for the alpha-numeric reading equipment could be in (1) preparation of computer input, (2) data transmission, (3) language translation, (4) catalog indexing, and (5) automatic typesetting. However, for optical reading in general, "(o)ne of the major difficulties . . . is to obtain clearly printed characters on the transaction documents. If optical reading is (to be) adopted by commerce, . . . business equipment manufacturers will not only have to provide machines to which the special typefaces can be fitted, . . . but in addition they will have to improve the general quality of print produced . . . ." (p. 77)

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Ovink, G. W.
LEGIBILITY, ATMOSPHERE-VALUE AND FORMS OF PRINTING TYPES
Leyden, A. W. Sijthoff's Uitgeversmaatschappij, 1938, 253p.

Problem: Determine the state-of-the-art of the legibility/readability, esthetic quality, and styles of printing-type faces.

Procedure: The below outline of contents indicates the book's scope and richness:

- I. The legibility of printing types.
  - A. The problem.
  - B. Theoretical foundations of the legibility of isolated letters.
  - C. Variations of the shape in proper sense.
  - D. Variations of the thickness of the constituent parts.
  - E. Theoretical foundations of reading of letters in context; the difference between the reading of isolated characters, of single lines and of several lines.
    - 1. The problem.
    - 2. Recognition of single characters.
    - 3. Recognition of single words.
      - a. Gestaltfactors.
      - b. Space and outline.
      - c. Boldness.
      - d. Experience.
      - e. Importance of upper half.
      - f. Serifs.
      - g. Horizontal extension.
      - h. Vertical extension.
    - 4. Recognition of lines of words (reading in a proper sense).
  - F. The measurement of reading-speed of a line of words.
  - G. The judgment of the subjects on legibility.
  - H. Summary and application of the results.
    - 1. The studies on typographical factors influencing speed of reading by Tinker and Paterson.
    - 2. Style of type face, e. g. FRAKTUR vs. ANTIQUA.
    - 3. Size of type and length of line.
    - 4. Space between lines.
    - 5. Legibility of small print.
      - a. Newspapers.
      - b. Time-tables, dictionaries, etc.
      - c. Continuous texts.
    - 6. Colour and surface of paper.
- II. The atmosphere-value (esthetic quality in relation to content) of type faces.
  - A. (chapter 9. )
    - 1. Description and method of investigation.
    - 2. Former studies.
    - 3. (Experimental) series VIIa.
    - 4. (Experimental) series VIIb.
      - a. The types.
      - b. The questionnaire.
      - c. The instruction.
      - d. Conditions.
      - e. Results.
  - B. The influence of margin, interlineage, colour and quality of paper.
    - 1. Questionnaire.
    - 2. Material.

3. Interlineage.
4. Margin.
5. Colour.
6. Paper.
7. Proceeding.
8. Results.

III. Short historical review of the modern printing type.
- A. Introduction.
- B. United States.
- C. England.
- D. France.
- E. Germany.
- F. Other countries.
  1. Spain.
  2. Holland.
  3. Italy.
  4. Czechoslovakia.

IV. Appendices (interspersed at various points in the text).
- A. Technical Introduction.
- B. Description of the qualities.
- C. Description of the type faces.
- D. List of the most important modern printing types.
- E. Selected references.

New experimental results (too numerous to mention specifically) have been included along with the discursive review. For this new experimentation, the author discusses the problems, apparatus, subjects, and experimental procedures involved. The results include subjective responses ("feeling tone" and legibility) to the type faces individually and when in context. Responses to individual letters are in terms of what the subject thought he saw, i. e. a description of the letter. E. g., the subject saw "a flattened circle, with a distinctive vertical bar.". . (p. 27), identifying it as an "a". In defining legibility, the author follows Pyke, with the reservation that he gives an illustration rather than a definition. Comments are also made on the "subjective facility (feeling of ease)" and the "objective facility (consumption of energy)." (p. 9) Atmosphere-value is defined as consisting of "those properties by which it (the type face) excites feelings within the reader." (p. 127) A technical introduction, which is unusually comprehensive for its brevity, discusses type-founding and -setting by describing technique, spacing and fitting, logotypes and kerns, lining systems, typesetting and composing machines, and non-typographical lettering.

Result: From the point of view of legibility; the results of previous investigations, some inductions and deductions from them, and suggestions for further research along the same lines, are given. The new experimental results concern primarily the esthetic qualities of various type faces, and in the context of combination with the type of information they are designed to convey.

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2119 Paterson-1940a

Paterson, Donald G. and Tinker, Miles A.
HOW TO MAKE TYPE READABLE--A MANUAL FOR TYPOGRAPHERS, PRINTERS AND ADVERTISERS
New York, Harper, 1940, 209 p.

Problem: On the basis of surveys of current practice, experiments, and subject opinions, determine the effect of type style, type form, type size, line width, line spacing (leading), page layout, contrast direction, use of color in print and background, printing surface, optimal vs. non-optimal printing arrangements, and some interactions between these on the legibility/readability ("In general, we have used the words legibility and readability interchangeably to mean 'ease and speed of reading printed material at a natural reading distance'.") of printed reading material.

Procedure: Using the Chapman-Cook Speed of Reading Test, a total of 66,062 tests was given to 33,031 subjects in a total of 45 experiments. Two hundred to 10,000 subjects participated in each experiment. Forms A and B (for experimental purposes) of the Test were used in the "ordinary reading situation." Reading times were 1-3/4 minutes for both the standard and the changed typographical arrangements. While a review of previous work (as such) was excluded, a criticism of the Luckiesh and Moss book, a comment on Pyle's report, and a "complete" bibliography were included in this study. For most sections of the book, the remarks concerning experiments followed the results of a survey that determined current practices for the particular variable involved. In turn, the experimental comments were followed by the subjects' personal "reactions" to the stimuli presented. Experimental variables were as follows:

1. Type styles were

   | | | |
   |---|---|---|
   | SCOTCH ROMAN | BODONI | CHELTENHAM |
   | GRANJON | OLD STYLE | AMERICAN TYPEWRITER |
   | GARAMOND | CASLON | CLOISTER BLACK. |
   | ANTIQUE | KABEL LIGHT | |

2. Type forms were bold vs. ordinary, italic vs. upright, and upper- and lower-case vs. all capitals.
3. Type sizes were 6-, 8-, 9-, 10-, 11-, 12-, and 14-point.
4. Line width was varied between 5 and 45 picas.
5. Line spacing was varied between 0- (solid) and 8-point leading.
6. Page layout was considered for
   a. dimensions of the full page (4 x 6 to 11 x 14 inches),
   b. relative size of the printed portion,
   c. margins (presence or absence, how much, and what for),
   d. single vs. double column (and others),
   e. spacing and lines between columns (rule and no space to no rule and 2-pica space), and
   f. paragraphing arrangements.
7. Contrast directions were black-on-white and white-on-black.
8. Colors utilized numbered eight for the print and six for the background.
9. Printing surfaces considered were Eggshell, White Enamel, Artisan Enamel, and Flint Enamel.
10. Optimal (vs. non-optimal) printing arrangements discussed concerned the results of interactions between various typographical variables.

In addition to an introductory chapter, the main body of the study, and a summary of recommendations, the book contains several appendices, including ones covering experimental methodology and a conversion table for printing measurements. Tables of detailed experimental results (not included in the book) also are listed by title with the note that they may be procured from the American Documentation Institute.

Result: In addition to detailed textual summaries at the end of each chapter and in the last chapter, the authors present (1) printing specifications for ideal printed pages using (a) single-column composition and (b) double-column composition, and (2) a tabular summary of typographical recommendations. The latter is paraphrased below.

| factor | satisfactory | undesirable |
|---|---|---|
| type style | any commonly used modern or ultra modern | AMERICAN TYPEWRITER OLD ENGLISH |
| type form | upper- and lower-case, bold for emphasis and distance reading, and italics for emphasis only | all capitals |
| type size | 9-, 10-, 11-, or 12-point leaded and in optimal line widths | 6- and 7-point and larger than 12-point |
| line width | about 19 picas | less than 14- or greater than 28-pica |
| line spacing | | |
| 6-point type | 2-point leading at 14- to 28-pica line width | set solid at less than 14- or greater than 28-pica line widths |
| 8-point type | same | same |
| 10-point type | same | solid and 1-point leading for all line widths |
| 11-point type | 2-point leading at 16- to 28-pica line width | set solid at 16- or less, or greater than 28-pica line widths |
| 12-point type | set solid or leaded 1- or 2-point in line width of about 25 picas | set solid or leaded in 9- or less or more than 33-pica line widths |
| page layout | | |
| margins | 1/4-inch at top, outer and bottom; 3/4-inch at inner | wide margins unnecessary for legibility |
| columns | single or double | readers disliked single |
| column spacing | 1/2-pica space with no rule | inter-columnar rule or greater than 1/2-pica space unnecessary for legibility |
| contrast direction and colors | black-on-white or dark-on-light | white-on-black, dark-on-dark, or light-on-light |
| printing surface | dull-finish opaque stock | glazed in artificial light; and thin, semi-transparent stock |

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3351 Paterson-1940b

Paterson, Donald G. and Tinker, Miles A.

Minnesota U., Minneapolis

INFLUENCE OF LINE WIDTH ON EYE MOVEMENTS

Journal of Experimental Psychology, 27:5

(November 1940) 572-577, 1 ref.

Problem: Determine, through the use of eye-movement studies, the validity of optimal

line-widths, as previously ascertained in eleven reading-performance studies using 10-point, lower-case, SCOTCH ROMAN type, set solid on egg-shell paper stock.

Procedure: "In the first study (here), each of 20 college students read 10 paragraphs from the Chapman-Cook Speed of Reading Test, Form A, set in an optimal line width (19 picas) and 10 different paragraphs from Form B of the same test set in an excessively short line width (9 picas). In the second study, each of 20 additional college students read (10) paragraphs from Form A in the 19 pica width and 10 paragraphs from Form B in the excessively long line width of 43 picas. . . (E)ach study (yielded) the following five analytical measures: number of fixations, number of words per fixation, duration of pauses, perception time, and number of regressions. . . (E)ye movements were photographed by the Minnesota eye-movement camera." (p. 572)

Result: In the first study, there was "a marked increase (15.7 percent) in the average number of fixations in reading the 9 pica line width in comparison with the 19 pica optimum. . . Curiously enough, more time in reading the short line was spent on each fixation (pause duration percentage difference equals 8.1). Also for the short line there is a striking increase (24.7 percent) in the total perception time. The only apparent advantageous characteristic of the short line width is found in the fact that it was read with fewer regressions (14.2 percent decrease). . . The . . . factor that could account for the decreased efficiency in reading the short line would appear to be the difficulty in making maximum use of peripheral vision in the horizontal direction. . . The results for the second study . . . sho(w) that fixation frequency in reading the long line is definitely increased, whereas the average number of words per fixation is decreased. Furthermore, the average time devoted to fixations (pause duration) is slightly increased and, of course, total perception time as well. A most striking difference occurs with respect to the number of regressions. This amounts to 56.7 percent increase (for the long line). . . (and) come chiefly at the beginning of each line. . . We interpret the results to mean that an excessively long line width gives rise to a major difficulty in swinging back to the beginning of successive lines." (p. 574-576)

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2674 Paterson-1942a

Paterson, Donald G. and Tinker, Miles A.
Minnesota U., Minneapolis
INFLUENCE OF SIZE OF TYPE ON EYE MOVEMENTS
Journal of Applied Psychology, 26:2
(April 1942) 227-230

Problem: "(D)etermine the specific patterns of eye movements involved in reading an unusually large . . . and a very small size of type (each) in comparison with a medium size . . . ." (p. 227) This is in comparison with previous findings that showed "decreases (in) reading efficiency (as determined by speed of reading) if unusually large or small sizes are compared with 10 point as a standard." (p. 227)

Procedure: All type was lower-case SCOTCH ROMAN, set solid, in 19-pica line-widths, on egg-shell paper-stock. The first part compared 10- and 6-point, while the second compared 10- and 14-point type sizes. In each part, 20 college students read the standard (10-point) on Form A of the Chapman-Cook Speed of Reading Test, and then compared on Form B of the same test. Each reading consisted of 10 paragraphs. "(E)ye movements were photographed by the Minnesota eye-movement camera." (p. 227) In each case, the items measured were the following: fixation frequency, words per fixation, pause duration, perception time, and regression frequency.

Result: In the first part, "eye-movement measures show that 10 point type is read more efficiently. (It) requires fewer fixations . . . . Pause duration is . . . shorter and total perception time is appreciably less." Statistically, "(a)ll differences (were) . . . significant (beyond the 1 percent level) except for regression frequency." From these results and also from the "(u)se of the Luckiesh-Moss Visibility Meter . . . (i)t appears that the decreased efficiency with which 6 point type is read is due to reduced visibility. . . The results for the second (part) . . . again show . . ." an efficiency differential in favor of 10-point type. "The details . . ., however, are not the same . . . . Here a striking difference exists in frequency of fixations (21.1 percent increase for the 14-point)." Also, "(i)t is interesting to note that the direction of the difference in pause duration is reversed. . . The net result in terms of total perception time again favors 10 point type." Finally, "(t)here is a slight . . . favor(ing) of 10 point so far as number of regressions is concerned." In this second part, "(a)ll differences (were) statistically significant (beyond the 1 percent level) except for regression frequency . . . The factor responsible for reducing the efficiency with which 14 point type is read, seems to be due primarily to the increased amount of printing area that must be covered in reading a given amount of text." (p. 228-230)

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3355 Paterson-1942b

Paterson, Donald G. and Tinker, Miles A.

Minnesota U., Minneapolis

INFLUENCE OF LINE WIDTH ON EYE MOVEMENTS FOR SIX-POINT TYPE

Journal of Educational Psychology, 33:7

(October 1942) 552-555.

Problem: "(D)etermine the specific patterns of eye movements involved in reading optimal versus non-optimal line widths for six-point (lower-case, SCOTCH ROMAN) type set solid . . . on egg-shell paper stock." (p. 552) This is by comparison with the results of reading performance tests (in which it was) found that a very short line width (seven picas) and an excessively long line width (thirty-six picas) produced . . . an important retardation in speed of reading in comparison with an optimum line width of about fourteen picas." (p. 552)

Procedure: In the first part, twenty college students read "(t)en paragraphs from the Chapman-Cook Speed of Reading Test, Form A, . . . set in a thirteen-pica line width and ten paragraphs from Form B . . . set in a five-pica line width." (p. 552) In the second part, twenty college students read "(t)en paragraphs from . . . Form A, . . . set in a thirteen-pica line width and ten . . . from Form B . . . set in a thirty-six-pica line width."

(p. 552) Photographic records of eye movements were obtained, for both parts, with the Minnesota eye-movement camera. Measurements in these experiments were for the following: fixation frequency, words per fixation, pause duration, perception time, and regression frequency.

Result: "In only one respect (regression frequency) does the excessively short line have an advantage." (p. 554) In this respect and others, the "results parallel . . . findings for the reading of ten-point type (Paterson-1940b) . . . ." (p. 554) Again, the general "interpretation stressed the reader's inability to make maximum use of horizontal peripheral cues in reading an unusually short line of print." (p. 554) Statistical differences for this first part showed all differences "significant beyond the one per cent level." (p. 552) Results of the second part show "the biggest difference in reading the excessively long line . . . is the number of regressions (67.7 percent more). Pause duration is also lengthened as is perception time. . . The direction of all of the differences again parallels the results . . . for ten point type." (p. 554) Thus, "the eyes, in reading an excessively long line, are inaccurate in locating . . . the beginning of each new line." (p. 555) Statistical differences for this second part were "significant beyond the one per cent level . . . for regression frequency and pause duration . . .(; and) at the 2 per cent level . . . in perception time . . . (D)ifferences in fixation frequency and words per fixation (were) not significant." (p. 554)

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3269 Paterson-1943

Paterson, Donald G., and Tinker, Miles A.
Minnesota U., Minneapolis
EYE MOVEMENTS IN READING TYPE SIZES IN OPTIMAL LINE WIDTHS
Journal of Educational Psychology, 34:9
(December 1943) 547-551.

Problem: "(T)he present investigation was undertaken. . . (i)n order to provide an analytical picture of the oculomotor patterns accompanying the retardation in reading each of the smaller type sizes (6- and 8-point) in comparison with one of the larger ones (eleven point) . . . A (previous) comparison of . . . optimal (line width and leading) arrangement revealed that both (the smaller size) type(s) were read significantly slower than the larger sizes (9-, 10-, 11-, and 12-point) which were read with equal speed." (p. 547)

Procedure: Using the Minnesota eye-movement camera, "(e)ye-movement photographs of two . . . groups of twenty subjects each indicate(d) the precise changes in oculomotor patterns involved . . . (p. 551) In the first comparison, (subjects) . . . read ten paragraphs from the Chapman-Cook Speed of Reading Test, Form A, set in eleven-point

GRANJON type with optimum line width (twenty-two picas) and leading (two points), and ten different paragraphs from Form B of the same test in eight-point GRANJON type with optimum line width (sixteen picas) and leading (two points). In the second comparison, (subjects) . . . read . . . from Form A (as before) . . . and . . . from Form B in six-point GRANJON with optimum line width (fourteen picas) and leading (two points)." (p. 547) Parameters measured were fixation frequency, words per fixation, pause duration, perception time, and regression frequency.

Result: "In reading eight-point type there was a significant increase in fixation frequency, pause duration and perception time and a significant decrease in words read per fixation. Regressions were also slightly increased. . . For six-point type there was a significant increase in pause duration and perception time. The other measures, although not significantly different, were in line with the findings for eight-point type. . . (T)he main factor producing the changes in oculomotor behavior. . . appears to be . . . (r)educed visibility of the smaller type sizes . . . ." (p. 551)

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3347 Paterson-1944

Paterson, Donald G. and Tinker, Miles A.
Minnesota U., Minneapolis
EYE MOVEMENTS IN READING OPTIMAL AND
NON-OPTIMAL TYPOGRAPHY
Journal of Experimental Psychology, 34:1
(February 1944) 80-83, 6 refs.

Problem: Compare "eye-movement patterns employed in reading text in optimal and in non-optimal typography." (p. 80) The non-optimal typography was obtained by introducing, simultaneously, undesirable variations of the following factors that in a previous speed of reading test (with the exception of the last item) retarded performance 22.2 percent: "type size, line width, leading(,) color of print and background . . . (and) paper surface . . . ." (p. 80)

Procedure: "The optimal arrangement consisted of type set in ten-point with two-point leading, 19 pica line width, black print on white eggshell paper stock; the non-optimal, of text set in six-point set solid, 34 pica line width, white print (with black background) on white enamel paper stock (sic). All material was printed in SCOTCH ROMAN, lower case. . . Each of 20 college students read 10 paragraphs from the Chapman-Cook Speed of Reading Test, Form A set in the optimal arrangement and 10 different paragraphs from Form B of the same test set in the non-optimal arrangement. . . (E)ye-movements were photographed with the Minnesota eye-movement camera. . . The photographic records yielded the following analytical measures: number of fixations, number of words per fixation, duration of pauses, perception time and number of regressions." (p. 80)

Result: All differences were positive (except, of course, words per fixation) and were statistically significant "beyond the one percent level" (p. 81) except for pause duration, which was "at the five percent level." (p. 81) All differences were "larger than found when any single undesirable variable is concerned. This suggests that, when several undesirable typographical factors (sic) are combined, they operate together to produce inefficient oculomotor patterns although the effects are not additive." (p. 82)

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2675 Paterson-1946a

Paterson, Donald G. and Tinker, Miles A.
Minnesota U., Minneapolis

READABILITY OF NEWSPAPER HEADLINES PRINTED IN CAPITALS AND IN LOWER CASE

Journal of Applied Psychology, 30:1
(February 1946) 161-168

Problem: Determine the difference in readability of all-capital vs. capital and lower-case newspaper headlines at normal, table-length, and far reading distances, using variations in type-size, line-width (single vs. multiple-column coverage), and exposure method. Previous experimentation showed "that continuous text set in all capitals was read about 12 per cent more slowly than text set in lower case. (Few typographical factors exert such a retarding effect on reading speed.) (p. 161) Generalizing from these results . . ., the writers recommended the abandonment of all capitals printing (in spite of Tinker's previous finding that all-capitals, in isolated letters and words, had greater perceptibility, because this latter was a function of perceptibility without reference to speed of perception). This recommendation was sharply challenged . . ." (p. 167)---hence, the present investigations.

Procedure: Three studies (not factorial) were undertaken to investigate the above. They utilized the following parameters:

| experiment | I | II | III |
|---|---|---|---|
| investigators | Breland and Breland | Warren | Warren |
| primary variables | capitals and lower-case versus all-capitals | | |
| stimuli | single-column, five-word headlines | | 100, multiple-column, five-word headlines selected from Minneapolis papers 1934-1940 |
| type face | CHELTENHAM BOLD | | MEMPHIS BOLD |
| type size | 24-point | | 60-point |
| subjects (N) | ------ | 40 | 46 |
| testing number | single | single | group |
| viewing distance | 15 inches | 5-1/2 feet | approximately 6 - 17 feet |
| viewing angle | normal | normal | various |
| apparatus | Dodge Tachistoscope | Whipple Disc Tachistos. | screen shutter |
| exposure time | 50 milliseconds | 180 milliseconds | approximately 1 second |
| additional parameters | ------ | subjective judgment | ------ |

Result: "The results (of the first study) disclosed an 18.9 per cent difference in favor of the lower case headlines." (p. 167) In the "second study . . . both kinds of headlines were shown to be equally legible.". . (p. 167) by the conditions of the experiment and by

subjective judgments elicited afterward. In the third study, "(a)t a distance of six feet the legibility of the lower case banner headline was 5.3 per cent greater than the legibility of those set in upper case. At distances from ten feet to fourteen feet, both kinds of headlines were equally legible. At a distance of seventeen feet, however, the upper case headlines proved to be more legible. . . The writers conclude that . . . (c)aps and lower case printing provides characteristic word forms which serve as cues to the rapid and accurate reading of meaningful material. This advantage has been shown . . . for . . . headlines when exposed at the distances at which they are ordinarily supposed to be read. For reading at unusually great distances such as in billboard display advertising, the writers would insist that lower case is also to be preferred. In this special situation, a larger point size of lower case than of upper case would have to be specified. . . In conclusion, . . . (w)hen (the) rule (of the abandonment of all-capitals) is generally adopted, an occasional use of all capitals might be justified as a device for attracting attention." (p. 168)

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3360 Paterson-1947a

Paterson, Donald G. and Tinker, Miles A.
Minnesota U., Minneapolis
INFLUENCE OF LEADING UPON READABILITY OF NEWSPAPER TYPE
Journal of Applied Psychology, 31:2
(April 1947) 160-163, 4 refs.

Problem: A survey of newspaper practice revealed that amount of leading used ranged from solid set to 2-1/2-point, with 1/2-, 1-, and 2-point the most popular. "The purpose (of this) present study is to determine the influence of leading on the readability of newsprint and to secure reader opinions of legibility for the material used." (p. 160)

Procedure: "(R)eading material (consisting of Forms A and B of the Chapman-Cook Speed of Reading Test) was set in 7 point NO. 5 IONIC NEWSPAPER type in a 12-1/2 pica line width on newspaper printing stock." (p. 161) In each case, Form A, the standard, was set solid and was compared with the following amounts of leading in Form B: solid (control), 1-, 2-, 3-, 4-, 5-, 7-, and 9-point. In the reading test, 680 university students were divided into eight groups of 85 subjects each to be tested for each leading amount. In the subjective judgment experiment, "(a)n additional 221 college students ranked samples of the print according to apparent . . . (readability)." (p. 162)

Result: The following conclusions were derived from the results:

1. "All material with leading was read faster than text set solid." (p. 163)
2. "In comparison with set solid material, the 4 and 5 point leading produced differences with the highest significance (beyond the 1 percent level). . . One point leading is as effective in improving readability as larger amounts of leading except for 4 and 5 points. Nine point leading is less effective than most of the lesser amounts of leading." (p. 163) Specifically, the following rank was found (p. 161) (from the percent difference between means): 4-, 5-, 1-, 7-, 3-, 9-, and 2-point.
3. "Text with 4 and 5 point leading (also was judged) to be most legible. . . Material set solid (was) judged to be least legible." (p. 163) Specifically, the following rank order of leading was derived from the reader judgments: (p. 162) 4- and 5-point, 3-, 7-, 2-, 9-, and 1-point, and set solid.

"In view of practical considerations, readability and readers' judgments, 1 point leading is indicated for 7 point newspaper type in a 12-1/2 pica line width. This would also hold for a 12 pica line width since unpublished data of the writers show that variations in line width from 12 to 12-1/2 to 13 picas do not significantly affect readability of newspaper type." (p. 163)

* * *

2195 Paterson-1947b

Paterson, Donald G. and Tinker, Miles A.
Minnesota U., Minneapolis
THE EFFECT OF TYPOGRAPHY UPON THE PERCEPTUAL SPAN IN READING
American Journal of Psychology, 60:3 (July 1947) 388-397
Also in READINGS IN EXPERIMENTAL INDUSTRIAL PSYCHOLOGY, Milton L. Blum, Editor, (New York, Prentice-Hall, 1952) p. 275-282

Problem: Study the effect of various typographical factors upon the perceptual span in reading.

Procedure: Reading from two Forms of the Chapman-Cook Speed of Reading Test, eight groups of twenty college students each participated in oculomotor behavior experiments, in which there was a typographical variant (such as size of type) for each experiment. Measures compared were pause duration, fixation-frequency, and words, picas, and characters per fixation. The number of units (e.g. words) read per fixation yielded the perceptual span. Variations in pause durations were also noted.

Result: Typographical changes found to affect significantly the perceptual span in reading were as follows:

1. upper vs. lower case,
2. OLD ENGLISH vs. SCOTCH ROMAN
3. 6- and 14- vs. 10-point height (with 19-pica line width),
4. 9- and 43- vs. 19-pica line widths (for 10-point height),
5. 5- vs. 13-pica line width (for 6-point height),
6. non-optimal typographical factors combination vs. optimal typography, and
7. red print on green field vs. black print on white field.

Those that did not produce significant changes in perceptual span were as follows:

1. 11- vs. 6-point height (in optimal line widths), and
2. 13- vs. 36-pica line width (for 6-point height). Also, certain typographical variations produced significant changes in pause duration, with or without significant changes in perceptual span.

In general, typographical variation seems to be an important determinant of perceptual span in reading, with optimal typography favoring a large perceptual span and non-optimal significantly reducing it. It is noted that other factors, such as comprehension, may affect perceptual span more than typographical changes.

* * *

2204 Perry-1952

Perry, Dallis K.
Minnesota U., Minneapolis
SPEED AND ACCURACY OF READING ARABIC AND ROMAN NUMERALS
Journal of Applied Psychology, 36:5 (October 1952) 346-347

Problem: Determine "how much speed and accuracy of reading are lost by the use of ROMAN numerals." (p. 346)

Perry-1952

Procedure: "Thirty college students were asked to read (aloud) as fast and as accurately as possible sets of numbers (allowing one minute per set) from one to nine, 10 to 49, and 50 to 99 (arranged in random order) in both ARABIC and ROMAN numerals (typed on bond paper in PICA type, with an inter-numeral space of two typewriter spaces) . . . ." (p. 347) Speed and accuracy were the test criteria.

Result: Percentage differences for the increase in speed of reading of ARABIC over ROMAN numerals represented 50. 1 percent, 137. 5 percent, and 349. 4 percent more speed for the 1-9, 10-49, and 50-99 sets respectively. "All differences were significant at the one per cent level." (p. 347) Percentage differences for the decrease in errors of ARABIC over ROMAN numerals represented 75 percent, 96. 4 percent, and 97. 1 percent more accuracy for the 1-9, 10-49, and 50-99 sets respectively. "The first difference was significant at the five per cent . . . and the last two at the one per cent level." (p. 347)

* * *

2202 Poulton-1959

Poulton, E. C.
Applied Psychology Research Unit,
Cambridge (Gt. Brit.)
EFFECTS OF PRINTING TYPES AND FORMATS ON THE COMPREHENSION OF SCIENTIFIC JOURNALS
Rept. no. APU 346, 1959, 22 p., 8 refs.
Condensed version (utilized here) of this report appeared in Nature, 184:4701 (December 5, 1959) 1824-1825, 3 refs.

Problem: "(D)etermine the relative comprehensibility in scientific papers of four different styles of printing." (p. 1824)

Procedure: "Two passages of 1, 150 words were written on unfamiliar topics. The layout was that of a scientific paper, but without title, subheadings, summary or tables, etc. Both passages were printed in all four styles. . . Comprehension was . . . tested . . . by 17 questions, each of which could be answered in a few words. . . Altogether 275 scientists from the University of Cambridge acted as experimental subjects . . . ." (p. 1824) Typography was as shown in the following table:

| condition | I | II | III | IV |
|---|---|---|---|---|
| monotype series number and name | 7-MODERN EXTENDED NO. 1 | 101-IMPRINT | 7-MODERN EXTENDED NO. 1 | 327-TIMES NEW ROMAN |
| point size | 11 | 11 | 9 | 9 |
| letter height (inches) total | 0. 15 | 0. 15 | 0. 13 | 0. 13 |
| x-height (height of the lower-case letter x) | 0. 07 | 0. 07 | 0. 05 | 0. 06 |
| leading between lines (inches) | 0. 03 | 0. 02 | 0. 01 | 0. 01 |
| line length (inches) | 5. 2 | 5. 0 | 2. 8 | 2. 8 |
| columns per page | 1 | 1 | 2 | 2 |

Result: The following were the mean comprehension scores for each condition:

| condition | I | II | III | IV |
|---|---|---|---|---|
| percentage score | 63 | 58 | 56 | 58 |

"(C)ondition I was considerably easier to comprehend than any of the other styles . . . (This) is in line with the findings of Burt et al. . . . . The advantage . . . over condition II must be due very largely to the style of type . . . The average scores for comprehension were 61 per cent for the under 30's, 58 per cent for those between 30 and 39, and only 53 per cent for the over 40's. . . The single-column passages . . . were read more quickly than the double-column . . . . (Twenty-six) per cent . . . (had an) average rate of reading . . . less than 300 words per (minute). . . (and) failed to finish reading both (conditions III and IV) passages in the alloted time . . . . The faster readers tended to score more highly on the tests of comprehension. . . Rate of reading was not related to age . . . . There were no significant differences between scientific departments on any measure." (p. 1824)

* * *

2201 Poulton-1960

Poulton, E. C.
Applied Psychology Research Unit,
Cambridge (Gt. Brit.)
A NOTE ON PRINTING TO MAKE COMPREHENSION EASIER
Ergonomics, 3:3 (July 1960) 245-248

Problem: "Until more experiments have been carried out it is clear that printers, especially in (Great Britain), cannot be sure that they are printing in the style which is most helpful to their readers. What appears to be needed now is fairly specific research comparing styles of print . . . ." (p. 247)

Procedure: The following table "summarizes the recommendations on printing made by . . . Luckiesh and Moss (in) 1942; Burt, Cooper and Martin (in) 1955, also Burt (in) 1959; and Tinker and Paterson (in) 1940, also Tinker (in) 1960 . . .:*

| | recommended optimal printing | | |
|---|---|---|---|
| | Burt | Tinker & Paterson | Luckiesh & Moss |
| type style | OLD STYLE best, except possibly for scientists | only AMERICAN TYPEWRITER and CLOISTER BLACK not recommended | MODERN better than OLD STYLE |
| type form | - - - | roman better than all capitals or italics | italics insufficiently bold |
| boldness | only if eye defects | unnecessary | medium bold recommended |
| size | 10 point | 10 point | at least 12 point |
| leading between lines | 1 or 2 point | 2 point | 3 point or more |
| length of line | 3-1/2 to 5-1/2 inches | 3 inches | 2 inches or less |
| colour of print and paper | - - - | dark letters on light paper best. contrast alone matters | ditto; non-glossy paper and ink recommended |

(above from p. 245)

The remainder of the paper discusses the experimental evidence and difficulties in its interpretation.

Result: In conclusion, the author states that "(w)hen more research for special purposes

has been carried out, it may be possible to decide whether additional basic work is required. If so it will probably be of a rather different kind from most previous research in this field, in that it will be concerned with the interactions of specific variables, including as one the type of reader. . . What cannot be predicted for certain is the effects of a number of simultaneous changes.". . in the parameters of typography and environment." (p. 247)

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*See Burt-1959, Luckiesh-1942, Paterson-1940a, and Tinker-1960, all abstracted elsewhere in this volume; and also see C. Burt, W. F. Cooper, and J. L. Martin, A psychological study of typography, British Journal of Statistical Psychology, v. 8 (1955) 29-58.

* * *

2193 Pyke-1926

Pyke, Richard L.
Medical Research Council (Gt. Brit.)
REPORT ON THE LEGIBILITY OF PRINT
Special rept. series, No. 110
London, H. M. Stationery Office, 1926, 118 p.

Problem: Study the legibility of printing type faces in the light of past theories and research. The author states that "(l)egibility must be distinguished from terms like recognizability, perceptibility, etc. With these we are not concerned. Legibility has to do with reading." (p. 25)

Procedure: This is probably the first comprehensive state-of-the-art report in the field of the legibility (readability) of printing types. Because of its indicative nature, the book's table of contents is reproduced below to indicate the author's scope of coverage:

d. Procedure (general).

IV. The experiments.
   A. Series A, B, C, and D.
   B. Series 1-8.
   C. Series 9.
   D. Series 10.
   E. Questionnaires.

V. Conclusions.

VI. Acknowledgements.

Appendices.
1. a. Explanatory note to 'Historical Subject-Resumes'.
   b. 'Historical Subject-Resumes'. (these include the author, year, experimental problem or basis, experimental criteria, and results or judgments for an extremely extensive literature review---this section of 50 pages, from the perspective of history, probably the most significant portion of Pyke's work).
      (1) Contrast in thickness and thinness.
      (2) Criterion of legibility.
      (3) Definition of legibility.
      (4) Faces of types.
      (5) Illumination.
      (6) Indentation.
      (7) Leading.
      (8) 'Legibility' of letters.
      (9) Length of line.
      (10) Margin.
      (11) Paper and ink.
      (12) 'Projectors', or long sorts.
      (13) Punctuation.
      (14) Serifs.
      (15) Size of type.
      (16) Spacing.
      (17) 'The Ideal Type'.
      (18) Thickness of limbs.
   c. Index to names of authors appearing in 'Historical Subject-Resumes'.
2. Specimens.
   a. Type-faces.
   b. Nonsense-material.
3. List of books and articles used for reading by subjects in the present experiments.
4. a. Glossary to typographical and other terms used in this Report.
   b. List of Abbreviations.
5. a. Explanatory note to Table of References.
   b. Selected References.

The new experimental work (IV. and V. above) involved the use of the following faces:

Type no. 1 - OLD STYLE (Lanston Monotype Series No. 2)
Type no. 2 - MODERN EXTENDED (Lanston Monotype Series No. 7)
Type no. 3 - IMPRINT OLD FACE (Lanston Monotype Series No. 101)
Type no. 4 - MODERN CONDENSED (Lanston Monotype Series No. 39)

Type no. 5 - MODERN (Caslon Series No. 23)
Type no. 6 - OLD STYLE ANTIQUE (Lanston Monotype Series No. 161)
Type no. 7 - CUSHING (Lanston Monotype Series No. 17)
Type no. 8 - LINING GROTESQUE (Stephenson & Blake Series No. 10)

Experimental series A-D "were intended to compare (1) the effect of a normal with a low illumination on the reading performance, and (2) the difference in the legibility of the three standard styles: OLD STYLE, OLD FACE, and MODERN FACE." (p. 46) Paper used was knows as "Double Crown Basingwork Parchment Quad Foolscap 80-516", and was a matte white. The ink was a dead black. Type body size was "Long Primer" with 48 lines per page. In series A and B, the face was no. 1; in C, no. 3; and in D, no. 7. Subjects, who "varied considerably" in astigmatism and visual acuity, "read several tens of thousands of letters in every series." (p. 47) The main purpose of experimental series 1-8 was "(1) to re-test in better controlled conditions the three standard styles used in Series A, C, and D, and (2) to test in conjunction with (1) the comparative legibility of five sorts of face, each embodying a distinct and an important quality, viz:

1. Lateral extension of face (type no. 5).
2. Lateral compression of face (type no. 4).
3. Uniform thickness of limb (type no. 6).
4. Uniform thinness of limb (type no. 7).
5. Absence of serifs (type no. 8)." (p. 47)

Thus, this series involved the use of all eight faces listed above. Experimental test series 9 was carried out to determine "if tests of a totally different and less elaborate sort would confirm the results of Series 1-8." (p. 54) Experimental series 10 was "a rough attempt to corroborate in a different way Series 1-8, to discover a more realistic test than by using nonsense (as utilized in all previous series), and to utilize sense material by testing every type at every session." (p. 56) Finally, "sixty individuals were (subjectively) canvassed for their opinions as to the relative merits of the eight types. They were expressly asked to ignore the aesthetic aspect." (p. 58)

Result: "The experimenter believes that in the laboratory, Type 1 (OLD STYLE) was probably the most legible and Type 4 (MODERN CONDENSED) the least. He is far more doubtful (a) of the sizes of the differences and (b) whether the relative legibility of the types in the experiments holds in the ordinary world." (p. 60) Also, "the most legible type, in (a) subjective sense, is unlikely to be the same for all readers." (p. 60) Very interestingly, "the results indicate that to some extent it was its ordinariness which helped to make Type 1 the best . . . . If it is correct, to isolate and test a type's objective legibility must be almost impossible." (p. 60) In closing the author gives the following: "For the practical, typographical problems of legibility are still far---further than many have believed---from scientific solution. Such solution is not possible until the manifold problems of principle, method, and technique have been acknowledged to exist and themselves solved. For this purpose are needed fewer opinions and more facts." (p. 61)

* * *

2631 Rabinow-1954

Rabinow, J.

Diamond Ordnance Fuze Labs., Washington, D. C.

STANDARDIZATION OF THE 5 X 7 FONT

DOFL rept. no. TR-39, 15 Jan 54, 8p.

AD-221 312

Problem: Develop and propose a standard type font which is legible for human readers, but is for use as input to and output from automatic data processing equipment.

Procedure: Determine the desirable characteristics of the font, including its ready reproducibility, utility as machine-readable input, and adaptability to high-speed element or conventional printing output. If possible, select a font already used in some of the tasks envisioned for the standard. The face should not be esthetically undesirable.

Result: The following reasons are set forth for the proposed use of a 5 X 7 element grid: Fonts based on this grid already have widespread use in industry (e.g. high-speed printers). While a 5 X 7 matrix produces 35 elements (many more than necessary for machine recognition), a smaller number would result in a far less legible face and a higher error rate in machine recognition (since the failure of the machine to read or print a fewer number of elements would give a higher probability of error). A larger grid, although it would give a font designer much more freedom, would contain a far greater and hence less manageable number of elements, and would also decrease the stroke-width to height ratio (using the rules by which this font is constructed). Further, it would be desirable to standardize not only the "shape" (sic) but also the size. Two sizes (not specified) could possibly answer a majority of present needs. For reproduction by template milling, photocopying, or microfilming, some advantages over present type faces (such as constant stroke-width to height ratio) are discussed. For printing by elements, the aspects of present compatability and prospects for future development are also discussed. For machine reading of the characters (the primary purpose of the report), the proposed font would, possibly, theoretically permit reading speeds that would now be considered phenomenal. Finally, the pro's and con's of the font's suitability in the conventional reading situation are discussed. Specifically, it is pointed out that a simple "Optical Braille" for machine reading would have the advantages of compactness and simplicity. The basic objections to it are (1) that for many years there will be a need for print that is readable by both machines and humans, and (2) as mentioned above, the disadvantage of a lack of redundancy more than outweighs the advantage of simplicity by providing for a higher probability of error. For example, "the failure of the machine to print or read any one dot (of six employed to define up to 64 (sic) characters as is done in Braille) would result in a certain error." (p. 5) A double, parallel font (conventional letters plus special machine-readable marks) is dismissed for the same reasons plus the fact that it would seem reasonable that a machine capable of reading separate special

marks could also be designed to read the humanly legible characters, such as English type (especially since the double font would require a separate printing in any event).

* * *

3303 Rabinow-1962

Rabinow, J.

Rabinow Engineering Co., Rockville, Md.

5x9 FONTS

15 Jan 62, 1v.

Problem: Develop and test a machine-readable, alpha-numeric, type font based on a 5 X 9 matrix.

Procedure: General considerations of the proposed font(s) are discussed. The desirable characteristics of a business machine font are as follows:

1. It should be based on a regular geometric pattern for easy reproducibility by conventional equipment, i.e. by typing, conventional printing, high-speed computer output printing, and microreproduction.
2. It should be adaptable to reading by most character recognition machines now being developed.
3. It should be humanly legible and "aesthetically not too objectionable." (p. 2)

While a 5 X 7 matrix of elements could easily lead to characters that (for machine-readable purposes) are quite unambiguous, the 5 X 9 grid "gives the designer much more freedom and produces a character somewhat taller in relation to its width and, therefore, . . . more suitable for denser packing of characters per line . . . ." (p. 2-3) Characters for the primary set were made up of horizontal, vertical, and 45 degree angle lines. "We have made photoelectric tests (of these) characters (in large scale) in our laboratory equipment." (p. 5)

Result: Figures show the following fonts:

1. The ASA OCR font is a 5 X 9 compromise meeting the requirements of various machines and also providing sufficient redundancy to eliminate ambiguities and to provide a good "starting signal" when the characters are read right-to-left. However, "it doesn't lend itself particularly well to an alpha-numeric system . . .." (p. 3)
2. The Rabinow 59N1 numeric font (also based on a 5 X 9 grid) is designed to "give reasonably good starting signals when read from left or right and . . . be compatible with the (Rabinow 59A1) alphabetic font . . ., shown . . . and (the Rabinow 59S1) several symbols . . . (also) shown." (p. 3) Area analyses showed that the numeric "characters can be distinguished from each other when the line thickness is . . . one-half . . . two times . . . and three times normal. (They)

can also be distinguished . . . if the top or . . . bottom line is missing, as may occur in high-speed drum printers." (p. 4)

3. The Rabinow 59A2, 5 X 9, alphabetic font is a modification of style 59A1. In it some of the rules for forming characters were violated to "increase the reliability of reading (sic) and to improve the appearance." (p. 4)
4. The Rabinow 59SA1, 5 X 9, expanded, alphabetic font widens the characters somewhat (by the insertion between each vertical row of an additional space equal to 27 percent of the normal line thickness) for easier machine reading of some characters (e.g. M and W) and to cause less smudging in typewriting. The corresponding Rabinow 59SN1 and 59SS1 fonts are also shown. The resulting sets are "considerably more pleasant to the eye and can be read by the same logic as the regular 5 X 9." (p. 4)

In conclusion, "the fonts proposed . . . have not yet been tested in actual practice." (p. 5) Yet, "it is hoped that in the very near future typewriters (specification shown) and other office machinery will be available, equipped with these characters. We shall then be able to tell, under . . . operating conditions, how well this font can be read (by machines)." (p. 5)

* * *

3350 Rose-1946

Rose, Florence C. and Rostas, Steven M.
Smith Coll., Northampton, Mass. and Amherst
Coll., Mass.
THE EFFECT OF ILLUMINATION ON READING RATE
AND COMPREHENSION OF COLLEGE STUDENTS
Journal of Educational Psychology, 37:5
(May 1946) 279-292, 17 refs.

Problem: "(D)etermine the effect of changes in illumination intensities from 2 to 55 foot-candles* upon the reading rate and comprehension scores of college students." (p. 290)

Procedure: The following experiments were conducted:

I - part 1: 42 student subjects were divided into two equal groups, each reading a selection from the Equated Transfer Selections for use with the Harvard Reading films, under 10 and 2-3 foot-candles, respectively. The groups were then reversed to read two different selections under the opposite conditions of illumination.

part 2: The same conditions held for this part except that a total of 30 subjects participated and illumination levels were 10 and 28 foot-candles.

II - 32 subjects read four selections (from the above noted material) under the following conditions:

| reading order | selections | illumination | | time |
|---|---|---|---|---|
| group A (16 | one | 28 | ft-cd. | 10 min. |
| subjects) | two | 3-5 | ft-cd. | 20 min. |
| | one | 28-30 | ft-cd. | 10 min. |
| group B (16 | one | 3-5 | ft-cd. | 10 min. |
| subjects) | two | 28-30 | ft-cd. | 20 min. |
| | one | 3-5 | ft-cd. | 10 min. |

III - part 1: "Of an original group of twenty . . . , it was possible to obtain complete data from only eight pairs of students. In this experiment the students were allowed to complete one selection from an unpublished (reading?) test used at Smith College . . . The entire group of twenty was tested together under 7 foot-candles . . . ." (p. 283)

part 2: The following materials were read: two more selections from the Smith test plus a second form of the Michigan Speed of Reading Test (which utilizes green print). Group A read the materials under 50 foot-candles, while group B read under 3 foot-candles. Illumination level was varied with a rheostat. It was noted that there was a color change toward yellow as illumination was decreased.

IV - Twenty-seven subjects were "divided into two nearly matched groups." (p. 286) One group read two samples from the freshman Hygiene text, one each under first 50 and then 3 foot-candles, while the other group read the same materials under first 3 and then 50 foot-candles.

Reading rate and comprehension were the test criteria in all the above experiments. In addition to these, "(a) second part of the experiment(s) included a survey of the illumination preferred by students when they could control the light from an indirect lamp, with possibilities of variation from 0 to 250 foot-candles." (p. 288) The task involved reading (1) 5-1/2-point AGATE type in the large Webster Merriam Dictionary, and (2) 14-point ENGLISH type in Equated Selections for use with Harvard Reading Films.

Result: The following results were delineated:

1. "(R)ate of reading and comprehension . . . did not increase by a measurable amount with increased intensity of illumination." (p. 290) However, "(t)here was a slight indication of increase in comprehension with increases of illumination from 2 to 10 and from 3 to 30 foot-candles." (p. 290)
2. "There were wide individual variations in reading efficiency (rate of reading and comprehension) under different conditions of illumination." (p. 290)
3. "Students do not necessarily read most efficiently under the illumination intensity which they prefer." (p. 290)

The following observations were also advanced:

1. "Given sufficient light to distinguish print (2-3 foot-candles), and freedom to read the material at the preferred distance from the eyes, almost any factor other than

illumination seems to play a more important role in reading efficiency than illumination." (p. 290)

2. "The very low illumination intensities, 2-3 foot-candles, are not to be recommended for reading because of their effect upon posture, rather than because of their effect upon reading efficiency." (p. 290)

"Further studies need to be made . . . upon reading under normal free conditions in order to balance the widely publicized . . . recommendations for greatly increased intensities of illumination." (p. 290)

* - This "includes the extremes found in any classroom at Smith College." (p. 280)

* * *

2574 Rowland-1958

Rowland, George E. and Cornog, Douglas Y.
Courtney and Co., Philadelphia, Pa.
SELECTED ALPHA-NUMERIC CHARACTERS FOR
CLOSED-CIRCUIT TELEVISION DISPLAYS
Technical rept. no. 21, 1 Jul 58, 21 p.
Contract C13ca-646
AD-203 318

Problem: Design and test a set of minimum-size, upper-case, alpha-numeric characters that will be legible and appear to be normal on a Spanrad air-traffic control, television display screen.

Procedure: In describing the requirement for new characters, the report first discusses viewing circumstances in terms of character identity and individuality when viewed from any direction and mentions the following typographic characteristics pertinent to legibility: stroke-width, contrast and its direction, size, horizontal and vertical spacing, height-width ratio, and illumination level. Secondly, it describes the mechanical aspects of the environment by considering the effect on characters of (1) the number of scan lines, (2) skipped scan lines, (3) horizontal scan response, and (4) contrast setting. Recognizing that time for developing the character set was too short for complete statistical evaluation, the experimenters selected a team of three subjects to view approximately 3/8-inch high, white-on-black characters on a Spanrad screen in order to subjectively evaluate their comparative legibility and eliminate undesirable sets. From 67 commercial type faces, five remained. These were: MEMPHIS BOLD, MEMPHIS EXTRA BOLD, SPARTAN BOLD, SPARTAN BOLD ITALIC (numerals only), and SQUARE GOTHIC. More exhaustive variations in viewing circumstances then left MEMPHIS BOLD for letters and SPARTAN BOLD ITALIC for numbers. Representative reasons for eliminating some of the sets are given. Incorporating the reasons for previous selection and elimination, an entirely new character set was designed with several variants for each character. A similar elimination procedure devolved a single character for each letter and numeral in this set. Inverse and other types of orientation were considered for character differences; e.g. as between C and U, M and W, E and 3, Y and V, etc. Finally, MEMPHIS BOLD/SPARTAN BOLD ITALIC, a celluloid menu style not previously considered, and the newly devised set were compared. The criteria used in the design of the new character set included specification that the characters should be (1) small enough to allow a maximum number of alphanumeric tags on the screen, (2) large enough to minimize recognition error (i.e., maintain legibility), (3) so designed that loss of a raster (scan) line would not cause such errors as mistaking an "E" for an "F", and (4) designed for projection onto a horizontal plotting table with

optimum legibility when viewed from any orientation (i.e. location around the table or position of character on the table).

Result: Recognizing the caution of needed empirical evaluation, the newly devised set was ascertained to be superior to the others on the Spanrad display. General rules used in building the set are represented by the following excerpts:

1. all characters have same vertical height,
2. maximum width to height ratio of 3:4, with noted exceptions,
3. vertical and diagonal stroke width to height ratio of 1:5-1/3, with noted exceptions,
4. horizontal stroke width to height ratio of 1:4, with noted exceptions,
5. stroke junctions generally squared, and
6. serifs, nulls, offset, and cutoff, as appropriate, used to eliminate orientation confusion.

* * *

2720 Schapiro-1952

Schapiro, Harold B.

Rochester U., N. Y.

FACTORS AFFECTING LEGIBILITY OF DIGITS

WADC technical rept. no. 52-127,

Jun 52, 17p., 28 refs.

Contract AF 33(038)18317

AD-1 117

Condensation of doctoral thesis

Problem: Determine how the legibility of single digits is affected by the interactions of style, illumination, and stroke-width to height ratio.

Procedure: The author first gives a review of previous work. Then, as a speed-of-reading test, twelve subjects, ages 19-33, with "normal" vision, each tachistoscopically read 3200 black-on-white digits in all possible combinations of the following parameters, with each digit being read five times for every given combination. Styles utilized were AND 10400, BERGER, CRAIK, and MACKWORTH. Illumination levels were 0.011, 0.044, 0.145, and 0.975 foot-lamberts. Stroke-width to height ratios were 1:5, 1:6.25, 1:8, and 1:10.

Result: Variance analysis (including the "t" test for significantly high variances) of the results indicated (1) illumination level was the most important parameter and there was marked improvement in performance up to 0.044 foot-lamberts but relatively little more for higher brightness levels, (2) the MACKWORTH digits were most legible with AND 10400 a very close second, (3) stroke-width to height ratios of 1:5 and 1:6.25 were superior to the others tested, and (4) except for illumination, the differences between subjects were more important than the other two variables. Correlation with the results of other investigators was shown for all parameters of the investigation. Also, informal interviews indicated that the 1:10 stroke-width to height ratio and the angularity of the BERGER digits were both disliked.

* * *

3339 Scott-1903

Scott, Walter D.

Northwestern U., Evanston, Ill.

THE THEORY OF ADVERTISING

Boston, Mass., Small, Maynard and Co., 1903, 240 p.

Problem: Study the effect of grouping, motion, color, type size, angle of viewing, contrast, comprehension, relevance, repetition, shape, complexity/simplicity, esthetic quality, convenience, significance, apparent size, and illusion of characters, words, and typographic environment in advertising media. Also, specifically determine (1) the legibility of type in railroad time-tables, and (2) the effect of contrast direction on the legibility of printed material.

Scott-1903

Procedure: The following table of contents delineates the scope of the book:

I. The theory of advertising.
II. Attention.
III. Association of ideas.
IV. Suggestion.
V. The direct command.
VI. The psychological value of the return coupon.
VII. Fusion.
VIII. Psychological experiment.
IX. Perception.
X. Apperception.
XI. Illusions of perception.
XII. Illusions of apperception.
XIII. Personal differences in mental imagery.
XIV. Practical application of mental imagery.
XV. Conclusion.

In the experiments concerning the legibility of type in railroad time-tables, 4 to 12 subjects participated in accuracy/speed reading tests involving a SMALL-FACE and a LARGE-FACE type, each of which was presented in both medium and bold stroke-widths. The contrast experiments were not delineated for procedure.

Result: The following observations resulted from the "time-table" experiments:

1. "(T)he LARGE-FACE type is easier to read and is not so subject to error as the SMALL-FACE type." (p. 125)
2. "(T)he lighter face type increase(d) the chance of errors . . . and increase(d) the time necessary to read . . . ." (p. 128)

In a "series of laboratory experiments . . . black letters on a white background were seen oftener than the white type on a black background." (p. 139) Finally, general observations concerning the parameters mentioned above are as follows:

1. "The easier and more pleasant the type is to read, the greater are the chances that it will be read and have the desired effect." (p. 129) Also, since they are only symbols, "(t)ype forms must not be regarded as a production of artistic demands, but as a product of the demands of convenience. . . Those forms of type . . . best perform their functions which are so easy of interpretation that they are not noticed at all." (p. 138)
2. "About four letters, four simple pictures, four geometrical figures or easy words are as much as we can see or attend to at once." (p. 7) And also, "the power of any object to force itself into our attention depends on the absence of counter attractions." (p. 9)
3. A corollary to the above rule of four states that ". . . the width of perception for printed words is about four." (p. 140)
4. "(T)he power of any object to attract our attention depends on the intensity of the

sensation aroused. . . (M)oving objects produce a stronger sensation than objects at rest. . . (R)ed is the color having the greatest attention value, green is the second and black the third. Black on a white background is more effective than white on . . . black . . . ." (p. 12-14) Corollary to this is the concept that ". . . white objects appear larger than black ones. . . Red, orange, and yellow objects look larger than objects of the same size which are green and blue." (p. 171) Also, ". . . red objects look closer than green ones." (p. 172)

5. "(T)he attention value of display (large and heavy) type increases in almost exact proportion to the increase of its size." (p. 14)
6. "Objects that fall under the direct gaze of the eyes make stronger visual impressions than those which fall out of the focus." (p. 14-15)
7. "(T)he attention value of an object depends upon the contrast it forms to the object presented with it, preceding or following it." (p. 15) Thus, ". . . when red and green are placed in juxtaposition. . . red looks redder and . . . green looks greener." (p. 17)
8. "(T)he power which any object has to attract our attention, or its attention value, depends on the ease with which we are able to comprehend it." (p. 18) Thus, "(s)tyles of lettering that are not easily read . . . are not so attractive (sic) as lettering . . . that (is) more simple and transparent in . . . meaning." (p. 19)
9. "(L)ettering that is distinct may be so united and so dimmed by the background that the whole is an indistinct blur." (p. 19)
10. "'(I)rrelevant words' . . . do not attract the attention . . . as often as relevant (ones) . . . ." (p. 19-20)
11. "(T)he attention value of an object depends on the number of times it comes before us, or on repetition." (p. 24)
12. "(T)he attention value of an object depends on the intensity of the feeling aroused." (p. 29) Thus, "(a) command in good display type at the beginning of an advertisement may express in a few words the intent of the entire advertisement." (p. 75)
13. "(T)he TRIANGLE is more attractive than a SQUARE, an OBLONG, or PARALLEL LINES . . . ." (p. 82)
14. "(A)ll things tend to fuse and only those things are analyzed that must be analyzed . . . and only after the process of analysis . . . do we perceive the parts." (p. 98-99)
15. "(W)e judge everything in the light of its environment---it fuses with its environment and the environment becomes a part of it." (p. 101)
16. "(W)e observe only those things which have significance for us . . . ," (p. 153) as for example the tail of the Q in distinguishing the Q from the O.

* * *

3298 Seibert-1959

Seibert, Warren F., Kasten, Duane F., and
Potter, James R.
Purdue U., Lafayette, Ind.

A STUDY OF FACTORS INFLUENCING THE LEGIBILITY
OF TELEVISED CHARACTERS

Journal of the SMPTE, 68:7 (July 1959) 467-472, 6 refs.

Problem: Determine the effect of viewing distance, viewing angle, image size, figure-background contrast, and elapsed viewing time on the legibility of upper-case, alpha-numeric characters when displayed on a television screen.

Procedure: Thirty-six subjects (college students, ages 17-35, and having normal near and far visual binocular acuity) were randomly seated at specific viewing stations in order to observe 252, randomly ordered, four character groups presented on a 24-inch television screen, whose picture-tube center was 6 feet above floor level. Viewing time was 10 seconds per group. Stimuli were FUTURA MEDIUM, upper-case, alpha-numeric characters displayed on the screen at 85 percent of their normal height. Characters eliminated from the set for the purpose of this experiment were I, O, R, Z, 1, 2, 7, and 0. The experimental design was a factorial of the following variables: Viewing distances were 6, 9.8, 13.6, 17.4, 21.2, and 25 feet. Viewing angles were 0, 19, and 38 degrees. Stimuli sizes were 60-point (ARTYPE catalog numbers 1158 and 1159), 48-point (number 1108), 36-point (number 1004), and 24-point (number 1209). Contrast directions (stimulus/field) were black/white, white/black, and white/medium-gray. The elapsed time variable was accomplished by showing the stimuli in three periods of approximately 15 minutes each, with 5 minute "filler" periods in between. Distance between characters in each stimulus group was three times the stroke-width between the two nearest parts of adjacent characters. Room illumination was measured at between 6.5 and 38.0 foot-candles in various parts of the room. Accuracy, the test criterion, was based on each subject making a "best estimate" of the content of each group.

Result: Generally, the "results indicate that no visual fatigue occurred, that black-on-white and white-on-black contrasts produced about equal visibility, and that characters subtending 10 min (or more) of vertical visual angle could be perceived with almost complete accuracy." (p. 467) Further, "information gathered during the course of the study . . . lends support to the following conclusions:

1. "Persons with average (or somewhat better . . .) visual acuity can engage in moderate. . . to heavy TV viewing for . . . one hour without . . . loss in . . . ability to perceive and record . . . information presented. . .
2. "(L)egibility (loss) . . . becomes pronounced at an angle (of viewing) between 19 and 38°. . .
3. "(U)nder most conditions, black-on-white characters are . . . more legible than white-on-black" (p. 471) with white on medium gray less legible than either of

the others. However, "when character size was reduced appreciably, the white-on-black characters become much less legible than the black-on-white . . . (p. 470)

4. "(V)iewing distance and character size influence(d) legibility . . ." (p. 471) In this, with screen centers "5-1/2 to 6 feet" above the floor, "the minimum distance recommendation should take account of the posture assumed and . . . a minimum (viewing) distance of five to six screen widths (maintained as) . . . acceptable . . ." (p. 471)

In making use of the study results, the following operational vs. experimental differences must be considered:

1. Subjects used in the experiment demonstrated "a relatively high level of visual acuity." (p. 471)
2. The experimental "'nonsense' visuals should . . . underestimate legibility of meaningful materials . . ." (p. 471)
3. "(I)t can only be assumed . . . that the characteristics of the TV system used . . . were 'typical' . . ." (p. 471)

* * *

3335 Silver-1940

Silver, Edwin H.
VISIBLE LICENSE PLATES AS A SAFETY AID
AAMVA Bulletin, 5:1 (January 1940) 20-22

Extract: The following material is excerpted from this review article:
"(F)actors (that) influence the accuracy of perception of the license plate of a moving car. . . (are t)he vision and mental attitude of the person observing . . .(,) the conditions which surround the license plate itself: the amount of haze . . .; dust or moisture on the plate; the roughness of the highway; the size and stability of the vehicle; the amount of illumination of the plate, as well as the color of the vehicle against which the tag is exhibited. . . (F)actors which are found in the plate itself. . . are: the color and gloss of the legend and background; the height, width, spacing and shape of the numerals and letters; the thickness or stroke of numerals; the ratio of height to width of numerals, and finally the reflection coefficients of the legend and background. (It is noted also) that a complementary color placed beside another tends to make it appear more deeply saturated." (p. 21)

"Legibility of a moving plate decreases if the letter or digit is too broad because of the positive after-image left on the retina by a series of lateral displacements caused by vibration. Broad letters likewise tend to run together, as will groups of letters when too closely spaced. The accommodation of the eye when fixing on a moving object also enters into the subject. . . Because of the . . . complication of (the above) . . . factors, Dr. Lauer conducted . . . research with the license plate as a fixed object, under the premise that things read at the greatest distance and under different conditions of illumination while motionless would be read best when moving." (p. 21)

"The results showed: (1) Dark legends on a light background offer the highest legibility in both high and low illumination. (2) Orange and red license plates are not efficient below four to five lumens or foot candles. (3) Bright yellow of about 575 mm (sic) makes a very good background. (4) Greens and blacks are best for numerals in various degrees of illumination. (5) Colors with long wave lengths are better for legend than background. (6) A 30 to 50 percent difference in reflection factors of legend and background offers the best

results. (7) The ratio between number and background should not exceed one to four. (8) Letters and numbers, if not black, should have a width-height ratio of 1 to 3 for best legibility. (9) The optimal stroke-width ratio of numberals (sic) is about 1 to 5. (10) Spacings 50 percent of the width of the numerals give the greatest legibility. (11) Numbers of four digits or less are preferable for legibility. (12) Groupings of two digits are most legible when exposed for sufficient time. (13) Metallic colors are best in low illumination, especially when exposed to a direct beam of light. They act as semi-reflectors." (p. 21-22)

* * *

3264 Sleight-1952

Sleight, Robert B.

Johns Hopkins U., Baltimore, Md.

THE RELATIVE DISCRIMINABILITY OF SEVERAL GEOMETRIC FORMS

Journal of Experimental Psychology, 43:4

(April 1952) 324-328, 11 refs.

Rept. no. 166-I-55, Special Devices Center,

Contract N5-ori-166

Problem: Concerning the relative discriminability of geometric forms, in sorting previous "literature into disagreements among comparable data and agreements among unrelated data, . . . one reaches the . . . conclusion that there can be no efficient ranking of geometric forms as an unequivocal abstract in itself. . . It seems appropriate, therefore, to investigate forms as they are 'good' in particular classes of situations and for particular purposes rather than to search abstractly for 'good' designs per se . . . Two aspects of discriminability were considered in this study: (a) the efficiency of the various forms in terms of 'sorting time' required, and (b) the 'attention-getting' value of the forms as measured by the priority of (subjects') selections." (p. 324)

Procedure: "The stimuli were six each of 21 different geometric figures, . . . constructed of black paper and mounted on 1-1/4-(inch) clear lucite squares. Each figure was the maximum size which could be inscribed within a 1-(inch) diameter circle." (p. 324) Names of the figures were as follows: AIRPLANE, CIRCLE, CRESCENT, CROSS, DIAMOND, DOUBLE-CONCAVE, ELLIPSE, HEART, HEPTAGON, HEXAGON, OCTAGON, PENTAGON, RECTANGLE, SEMI-CIRCLE, SHIELD, SHIP, SQUARE, STAR, SWASTIKA, TRAPEZOID, and TRIANGLE. "A circular board, 25 (inches) in diameter and painted flat white, was used as a display background. . . The board was set on a table 30 (inches) from the floor. The 126 figures were spread out in random order and in various orientations . . . . Overhead room lighting was used. . . (p. 325) Sixteen male and five female (subjects, who were told to emphasize accuracy rather than speed) participated" (p. 326) in two tasks. In the first, "each (subject) was instructed to sort first the kind of figure which, at a glance, seemed to 'stand out' or seemed to be 'easiest to sort quickly.' All six of these were . . . completed before another kind was sorted." (p. 325) The other

20 types followed the first in the same manner, with "the last group . . . that considered the most difficult." (p. 326) The second task "involved two variations on the above procedure: (a) The sorting order was predetermined and was different for each . . . (subject) . . . (b) When six of any given . . . figure were sorted, they were replaced by (the experimenter) in approximately their original positions . . . so that (the subject) always began to sort from among all 126 items." (p. 326)

Result: The "relative discriminability of geometric forms as determined by (a) mean selection order, and (b) mean sorting time" (p. 327) was as follows:

| forms | rank by selection order | rank by sorting time | groupings by significant differences in mean sorting time |
|---|---|---|---|
| SWASTIKA | 1 | 1* | A** |
| CROSS | 2 | 5 | A** |
| STAR | 3 | 6 | A** |
| AIRPLANE | 4 | 4 | A** |
| CRESCENT | 5 | 3 | A** - simple*** |
| DIAMOND | 6 | 9 | B |
| CIRCLE | 7 | 2 | A** - simple*** |
| HEART | 8 | 12 | C |
| TRIANGLE | 9 | 10 | B |
| DOUBLE-CONCAVE | 10 | 19 | D |
| SEMI-CIRCLE | 11 | 14 | C |
| SHIELD | 12 | 17 | C |
| RECTANGLE | 13 | 8 | B |
| ELLIPSE | 14 | 7 | B |
| SHIP | 15 | 13 | C |
| SQUARE | 16 | 11 | B |
| TRAPEZOID | 17 | 16 | C |
| PENTAGON | 18 | 15 | C |
| HEXAGON | 19 | 21* | D |
| OCTAGON | 20 | 18 | D |
| HEPTAGON | 21 | 20 | D |

(above from p. 326 & 327)

* - "Discriminability as measured by sorting time was approximately ten times faster for the first ranking than for the last ranking figure." (p. 328)

** - This was "(t)he most discriminable group . . . ." (p. 328)

*** - "Of the six best figures in terms of speed of sorting time, . . . two (as noted) might be considered 'simple' in the sense that this term is used by Gestalt psychologists." (p. 328)

As indicated above, "(a) high positive correlation was found between the ranking of figures

according to sorting time and ranking based on (subjects') order of selection of items according to their 'attention-getting' value. . . It would seem that the present study as well as the earlier researches supports the thesis that neither 'good' nor 'bad' are qualities intrinsic to form per se but an extrinsic evaluation that may be applied to any given form depending upon the total situation being considered and the purpose to be served." (p. 328)

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3277 Slivinske-1957

Slivinske, Alec J., and Crumley, Lloyd M.
Pennsylvania State U., University Park
HUMAN ENGINEERING INVESTIGATION OF AIRCRAFT COCKPIT VISUAL DISPLAYS: THE EFFECTS OF CONTRAST, COLOR, AND VIEWING ILLUMINATION ON THE LEGIBILITY OF LETTERS AND NUMERALS
Rept. no. NAMC-ACEL-392 (TED NAM AE-7047, Part 16a), 27 Feb 57, 13p., 3 refs.
AD-129 107

Problem: "(I)nvestigate the effects of contrast, color, and viewing illumination (and their interactions) on the legibility of printed letters and numerals." (p. 1)

Procedure: "The letters used were E, L, N, T, Y, and the numerals were 2, 4, 5, 7, and 9 (all from the AND 10400 set). . . (p. 2) They were presented (singly) under three degrees of contrast (46.45, 15.30, 5.16), two values of color (white on black vs. red on black), and under conditions of day viewing (30 foot-candles) as opposed to night viewing (.09 foot-candles). A total of 50 (student) subjects were run under 10 combinations of these conditions since the stimuli were not legible under the lowest contrast value (5.16) at the night illumination. . . (p. 11) The letters or numbers were flashed (3/16 inches high) onto a . . . ground glass viewing plate . . . 2-1/4 (by) 3-1/4 (inches) . . . at 28 (inches from the subject)." (p. 2)

Result: "Contingent upon the conditions of the study, the following conclusions were warranted by the findings:

1. "When the effects of contrast and color were analyzed independently under day and night viewing conditions, they failed to produce reliable effects on . . . legibility . . . .
2. "When . . . combined in a single analysis, viewing illumination was found to be reliably related to legibility. Specifically, day viewing produced significantly shorter read-out times than the simulated night viewing . . . . Neither of the other variables nor any of the interactions . . . yielded reliable effects. . .
3. "It was (shown) that the stability of legibility measures which (were) obtained after a relatively small number (20 here) of practice trials . . . provide(d) a useful

methodological finding.

4. "Slight differences between the rank orders of the letters and numerals . . . were noted under day and night viewing conditions. The correlation between ranks, however, was . . . statistically reliable." (p. 12) The rank order was as follows: day - N, E, L, Y, 5, 2, 9, T, 4, and 7; night - E, N, L, 9, 5, T, 2, Y, 7, and 4.

In general, except for day being significantly better than night viewing, the apparent superiority of (1) the high contrast ratio, (2) red on black in night viewing, and (3) white on black in day viewing, did not hold.

* * *

3324 Smith - 1958

Smith, G. W. and Israel, R. J.

OVERHEAD SIGNS

California Highways and Public Works, 37:11-12

(November-December 1958) 25-30

Extract: "The use of upper and lower case letters for guide signs . . . (is) of proven advantage in recognition and legibility . . . . The CALIFORNIA style of lower case lettering was subsequently utilized for directional signing by the major eastern toll roads. . . (and) has been adopted . . . for destinations on the interstate system. . . (W)hite letters on a dark background . . . (give) more effective nighttime legibility . . . One of the most important developments in the signing field has been the overhead illuminated signing . . . (p. 25) lighted . . . (by a) fluorescent . . . fixture . . . mounted below the sign in order to eliminate the objectionable daytime shadow of the lighting fixture on the sign face. . . (p. 26) (T)he largest . . . type frame covered by the standard plans is 10 (feet by) 60 (feet). . . (p. 28) (I)nterstate guide signs will have a green background and wid(e) borders, with rounded corners. The interstate manual reserves upper and lower case lettering for destinations only, so that (exit) distance, lane assignment, etc. will appear as all capital letters. This will involve the mixing of upper and lower case letters on the same sign. Perhaps the major difference in interstate (over California) signing will be the diagonal up arrow at the exit ramp . . . ." (p. 29)

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2721 Soar - 1955a

Soar, Robert S.

Vanderbilt U., Nashville, Tenn.

HEIGHT-WIDTH PROPORTION AND STROKE WIDTH IN NUMERAL VISIBILITY

Journal of Applied Psychology, 39:1 (February 1955) 43-46, 16 refs.

Problem: Study the effect of the interaction between height/width ratio (holding area

constant) and stroke-width on the legibility of numerals.

Procedure: "A total of 72 (subjects, having 95 percent or better visual acuity, and being from the university elementary psychology laboratory) provided six replications for all combinations of height-width proportion at four levels (10:3, 10:4.5, 10:6, and 10:7.5) and stroke width at three levels (.0167, .0125, and .0083 inches). . . The heights and widths of the finished (HAND-DRAWN) numbers were, in inches, respectively: (p. 43) .1313 X .0396, .1067 X .0483, .0934 X .0558, and .0834 X .0625. . . The stroke width to height ratios (thus) ranged from 1:8 to 1:5 for the widest . . . and 1:16 to 1:10 for the narrowest stroke width(s) . . . ." (p. 45) A pilot study indicated that 40 milliseconds at 1 foot-candle illumination in a tachistoscopic exposure would yield about half the responses correct. "The score for each (subject, therefore,) was the number of digits correctly identified. . . (p. 43) The data were treated by analysis of variance and covariance." (p. 45)

Result: "Height-width proportion and stroke width show(ed) no (significant) interaction. . . Height-width proportion was a source of variation in (legibility) significant beyond the 1 (percent) level for . . . numerals (0, 3, 4, 7, and 9), and beyond the 5 (percent) level for (the numeral 6) . . . . Stroke width was a significant (1 percent) source of variation for only (the) numeral (8). The most (legible) combination of height, width, and stroke width for all numbers (was) a height-width ratio of 10:7.5 and a stroke width to height ratio of 1:10. . . (p. 45) The only numbers for which one of the two widest combinations (of height-width) was not the most (legible were) the 5 and 9." (p. 44)

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3267 Soar-1955b

Soar, Robert S.
Vanderbilt U., Nashville, Tenn.

STROKE WIDTH, ILLUMINATION LEVEL, AND
FIGURE-GROUND CONTRAST IN NUMERAL VISIBILITY

Journal of Applied Psychology, 39:6 (December 1955)
429-432, 15 refs.

Problem: In determining numeral visibility, ascertain the effect of the following interactions: stroke-width vs. illumination level, stroke-width vs. contrast direction, illumination level vs. contrast direction, and stroke-width vs. illumination level vs. contrast direction.

Procedure: Forty college students (all having 100 percent normal visual acuity) viewed stimulus numerals (HAND-DRAWN and photographically reduced to about the size of 10-point type) in black-on-white and the reverse, in stroke-width to height ratios of 1 to 4 and 1 to 16, and under illumination levels of 0.5 and 500 foot-candles. "The forms of the numbers

followed those found to be optimal by Brown et al." (p. 430) In all, "five replications of eight combinations of experimental conditions" (p. 432) were studied. The task involved "a variant of the method of constant stimuli, in which each subject observed the . . . numbers at three different distances under one of the combinations of experimental conditions. The score for each subject was an estimated threshold distance at which he would have been expected to read half of the numbers correctly." (p. 430)

Result: Neither stroke-width nor contrast direction "showed a significant influence on visibility, but illumination level was highly significant. Stroke width interacted significantly with illumination level" (p. 432) and with contrast direction. "The interaction between illumination level and (contrast direction) . . . was not significant; further, there was no suggestion in the data that such an interaction exists. The interaction of all three variables was significant." (p. 432) In addition, the following general statements were made:

1. The problem of contrast direction (at least for B/W vs. W/B) "can be settled only if the optimal stroke width is determined separately for each, and for the illumination under which the comparison is to be made." (p. 431) In converse, "(b)oth illumination level and (contrast direction) must be known to specify the optimal stroke width." (p. 431)
2. "If the application is subject to a wide range of illumination levels, it seems likely that the best choice of stroke width would be that which would be optimal at the lowest illumination level, since visibility would be expected to increase more rapidly with rising illumination than it would decrease as a function of nonoptimal stroke width." (p. 431)

* * *

2722 Soar-1958

Soar, Robert S.

Vanderbilt U., Nashville, Tenn.

NUMERAL FORM AS A VARIABLE IN NUMERAL VISIBILITY

Journal of Applied Psychology, 42:3 (June 1958) 158-162, 9 refs.

Problem: Compare the legibility of individual numerals from five experimentally developed sets that differ from each other in numeral form.

Procedure: Previous work concerning legibility comparisons between experimental numeral sets shows contradictions in the results. Even for "errors in reading maximally legible numeral forms", (p. 159) previous work of the author shows the following confusions: 0 with 6 and 9; 1 with 4; 2 with 8; 5 with 6 and 8; 6 with 4; 8 with 6 and 9; and 3, 4, 7, and 9 with other numerals in random fashion. "These . . . patterns of confusion provided the basis for designing experimental numera(l sets). An attempt was made to

minimize the . . . common . . ., and to emphasize the unique elements. . . Three . . . numera(l sets) were prepared . . .: one by altering stroke width, a second by altering form, and a third in which both alterations were made simultaneously. A fourth set . . . (was) prepared which duplicated . . . those designed by Mc LAUGHLIN. The control (a fifth set of) numerals were those whose form had been found to be maximally visible by Brown . . ., and whose optimal height-width combination and stroke width had been determined by (the author). . . The stimulus numerals (three sets) were hand-drawn, 2 inches high and 1.5 inches wide, and with stroke widths of .2-.4 of an inch. . . Mc LAUGHLIN's numerals were . . . the same external dimensions, but with a maximum stroke width of .37 (inches). . . These were then reduced to one-twentieth . . ., resulting in . . . figures approximately the size of 10-point type. . . One hundred college student (subjects, having normal visual acuity for the distance required) . . . provid(ed) 20 replications of the five experimental conditions . . . (in the) Harvard Tachistoscope . . . The exposures were 40 milliseconds . . . under approximately one foot candle of illumination. . . (A)nalysis of variance and covariance. . ." (p. 159) were made on the data.

Result: "(S)ix of the experimentally developed numerals (0, 1, 2, 5, 6, and 8) were shown to be significantly more visible than the current standard." (p. 162) However, "(t)he data suggest that boldness, rather than form, is the important factor . . . ." (p. 160) Also, "there are suggestions (from this) and in (a previous) study . . . that . . . visibility may be increased by allowing stroke width to vary from numeral to numeral . . ." (p. 160) and/or within one numeral, particularly for their unique elements. Numeral sets were identified as follows: A = the standard (BROWN?), B = changes in stroke width (McLAUGHLIN?), C = changes in form (EXPERIMENTAL), D = changes in stroke width (EXPERIMENTAL?), and E = changes in form and stroke width (EXPERIMENTAL). The following significant differences were found (with indications as to important variables):

0 - AC < D < BE (beyond 1/10 percent) differences not clear, i.e. D vs. B vs. E
1 - AC < BDE (beyond 1/10 percent) differed only in boldness, except rounded ends in B
2 - C < A < DE < B (beyond 1/10 percent) form important, as well as boldness
3 - no significant differences, however A, C, D, and E were identical in form
4 - same as 3
5 - A < C < BD < E (beyond 5 percent) form and stroke width both important
6 - ACDE < B (beyond 5 percent) form and stroke width both important
7 - same as 3
8 - AC < BDE (beyond 1 percent) boldness important
9 - no significant differences

Stroke width for the whole number improved 0, 1, and maybe 2; stroke width for a part of the number (and to a certain extent form of the number) improved 5, 6, and 8; and form improved 2, 5, and 6. Openness of the internal white space in the numbers was also seen as a factor.

* * *

2579 Solomon-1956

Solomon, David

Bureau of Public Roads, Washington, D. C.

THE EFFECT OF LETTER WIDTH AND SPACING ON NIGHT LEGIBILITY OF HIGHWAY SIGNS

In HIGHWAY RESEARCH BOARD, PROCEEDINGS OF THE THIRTY-FIFTH ANNUAL MEETING, 1956, Fred Burgrraf and Elmer M. Ward, Editors, (Washington, D.C., National Academy of Sciences-National Research Council Publication 426, 1956), Vol 35, 600-617, 3 refs.

Problem: "(D)etermine the effect that (letter width, i.e., height-width ratio, and) spacing between letters (i.e., horizontal character spacing) of words, used in highway signs, had on their nighttime legibility." (p. 600)

Procedure (primary): "More than 2,500 observations were made by 36 observers while driving an automobile at 30-(miles per hour at night). White reflectorized (all capital) letters, 10 (inches) high, were displayed on a black nonreflectorized background. Three different alphabets were used. Two of these, the Standard (U.S. Bureau of Public Roads) SERIES C with narrow letters and the wider SERIES E, were cut from reflective sheeting The third alphabet, identified as SERIES ED and similar in width to the SERIES E, was designed . . . using 1-1/4-(inch) diameter plastic reflectors to form the letters. The spacings between letters were increased as the lengths of the six test words (BALK, DUCK, FARM, NAVY, STOP, and ZONE) were extended from normal to 20, 40, and 60 percent above normal." (p. 600)

Result (primary): "As interletter spacing was increased, the legibility distances also increased for all three alphabets until word lengths were 40 percent above normal. The resulting gain i(n) legibility at this point was 15 percent for SERIES C, 16 percent for . . . E, and 7 percent for . . . ED. . . When word lengths were normal or no more than 10 percent above . . ., test signs with the . . . ED alphabet (had) greater legibility. . . (A)t corresponding letter spacings the SERIES E alphabet was legible at a greater distance . . . than the narrower . . . SERIES C . . ., the differences . . . rang(ing) from 23 . . . to 27 percent. (However, a) word with letters of the . . . C . . . is shorter . . . than one with letters of the . . . E for a given spacing, and a comparison of legibility distance per inch of word length showed that the . . . C . . . was . . . superior to the . . . E." (p. 600)

Procedure (height variant): "Also studied was the probable effect of increasing the letter height of the narrower alphabet until the legend area equaled that of the wider alphabet." (p. 600)

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Result (height variant): "At the point of equivalent legend area and spacing, the two alphabets proved to be equally legible." (p. 600)

Result (general): "The study findings point to the importance of sign proportions and provide an improved means for efficient determination of legend design. Where vertical dimensions restrict sign letter heights to something less than desirable, increased spacing between letters can help to compensate for the loss of legibility distance that would otherwise occur." (p. 600)

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3354 Spragg-1952

Spragg, S. D. S. and Rock, M. L.

Rochester U., N. Y.

DIAL READING PERFORMANCE AS A FUNCTION OF BRIGHTNESS

Journal of Applied Psychology, 36:2 (April 1952) 128-137, 15 refs.

Problem: Determine the speed and accuracy of reading "photographic reproductions of instrument dials as a function of the brightness of the dial markings." (p. 136)

Procedure: Twenty (experiment I) and ten (experiment II) young adult males, all vigorously screened for excellent visual abilities, participated in two speed and accuracy scored experiments in which the task was to read photo-reproductions of circular dials, through an 11-inch by 14-inch aperture at a distance of 28 inches. The stimuli each contained three rows of four dials each, white-on-black, and in high contrast (greater than 10 to 1). In Experiment I, the dials were each 2.8 inches in diameter and contained 100 units, divided (by scale marks and numbers) every 10 units. A sweep pointer indicated the reading. In Experiment II, the dials were of the same configuration except that they were 1.4 inches in diameter and there were scale marks for every unit. Illumination (from behind subject) had a color temperature in the neighborhood of $2400^{o}$ K. Illumination levels for Experiment I were 0.005 (just above cone threshold), 0.018 and 0.022 (straddling a pre-determined difficulty transition area), 0.296 (intermediate), and 6.0 (relatively high) foot-lamberts. Similar adjudications for Experiment II provided illumination levels of 0.005, 0.01, 0.05, 0.1, and 1.0 foot-lamberts. Dark adaptation was accounted for.

Result: "Both for time and for error frequency scores a critical brightness level was found at approximately 0.02 foot-lamberts. At brightnesses below this level performance was increasingly impaired; above this level increases in brightness produced little or no improvement in visual performance. . . These findings suggest that for the night-time operation of equipment where dial-reading and comparable visual tasks are involved

brightness values should be kept safely above the critical . . . level. . . (A)t higher (than 0.05 foot-lamberts) levels . . . brightness ceases to be a significant variable." (p. 136) Further, the authors compare their results with those of previous investigators, and in one instance make the very interesting statement that "contrast, defined physically, is independent of illumination." (p. 135) The following limitations are applied to the results: parallax error due to angle of viewing was not possible, contrast on photo-reproductions may be lower than on actual dials, reflections from a glass face are lacking, and data were taken under non-fatiguing conditions.

* * *

2723 Squires-1957

Squires, Paul C.

Naval Medical Research Lab., New London, Conn.

NEW DIGIT DESIGNS FOR USE UNDER REFLECTED RED LIGHT OF LOW BRIGHTNESS

Rept. no. 284, 20 May 57, 11p., 11 refs.

AD-159 357

Problem: "(D)esign a set of digits uniquely appropriate for use under reflected red light of low brightness, especially for use on rotating dials." (p. ii)

Procedure: "Every effort was made to design the digits as nearly as possible in harmony with our number perception habits. That is to say, radical novelties (were) incorporated in a NEW design only where deemed absolutely essential for speedy and accurate reading under low red light. . . In (this) NEW set of digits, uniform stroke-width (was) sacrificed wherever necessary in the interest of optimum recognizability. . . (p. iii) The digits were cut out of white Strathmore Bond paper having a reflectance of 80 per cent, under the condition of a (matte) black background; these were attached . . . to a clear Plexiglass dial 1 (foot) in diameter. . . (,) vertically mounted in such manner that it could be rotated. The dial was mounted immediately behind a matte black disc of 1 (foot) diameter . . . with an open sector large enough to permit one digit to be shown at a time . . . at any desired position on the arc. . . Two sets of digits were tested: (1) The NAMEL (and) . . . (2) The NEW designs. Each digit in both sets was 42 (millimeters) high, subtending a visual angle of 28.6 minutes at a viewing distance of 16.5 (feet). . . (I)lluminating the digits . . . was . . . an overhead . . . egg-crate . . . fluorescent, equipped with two 8-watt tubes (e)nclosed in red acrylic cylinders. . . accepted as standard in submarine lighting. The brightness of the digits . . . was 0.165 (foot-lamberts) . . . Each observer . . . was shown one digit at a time in the upside down position. . . (,) whereupon (he) began to increase the brightness of the visual field (in the Luckiesh-Moss Visibility Meter) until he . . . could 'just barely but with certainty' identify the digit. . . Seven . . . Navy personnel . . . served . . . (as observers). . . (p. 3) Analysis was by variance technique." (p. 8)

Result: "A set of digits was designed, which was uniquely appropriate for use under reflected red light of low brightness levels, especially in connection with rotating dials. . . Findings . . . (were) with regard to the comparative absolute thresholds of the NEW digits and the NAMEL . . . set . . . used as criterion. . . (p. iii) (O)nly two variances differ(ed) significantly from chance: between types and between observers. Both . . . (were) beyond the 1 (percent) level . . . (T)here (was) a significant perceptual difference between the NEW and NAMEL types of (and individual) digits. Since the interaction between types and observers (was) not significant, the observers presumably behaved similarly with respect to the types of digits. . . (p. 4) (However, t)hese NEW digit designs should under no circumstances be used for general purposes. . . (p. iii) Some typical comments by the (observers) follow:

'A perfect "8"' (this was a NAMEL '3').

'"8", "2", and "4" are good' (said of NEW).

'"3" and "8" not confused' (NEW).

'"4" is good because of longer extension of horizontal line segment' (NEW).

'This "8" (NEW) is better than the other "8"; I don't confuse this "8" with "3".'

'I don't mix up this "2" (NEW) with any other number.'

'The "4", "8", "2", "0" look really good under this low light' (NEW).

'This "8" I don't confuse with "2"' (NEW).

'This "3" is like an "8"' (NAMEL).

'"2" (NAMEL) looks like a "5" or "7".'

'I confuse "2" with "8" at lower light levels' (NAMEL).

'The "1" like "0" when very dim' (NAMEL).

'"3" a hard number to read' (NAMEL).

'I confuse "2" and "5", "3" and "8", "5" and "3"' (NAMEL).

'I confuse "3" with "8" a lot' (NAMEL)." (p. 5)

* * *

3337 Starch-1914

Starch, Daniel
Wisconsin U., Madison
ADVERTISING: ITS PRINCIPLES, PRACTICE, AND TECHNIQUE
New York, Scott, Foresman and Co., 1914, 281 p.

Problem: "(A)nalyze and . . . put together in systematic form the available facts and elementary principles of advertising." (p. 3)

Procedure: The following table of contents shows the scope of the book:



Result: The following statements are made concerning typography and layout:

1. "(T)he size of the display type for a given advertisement. . . depends on whether the headline is to be the chief means of attracting attention . . . . If only an insignificant illustration is inserted, the heading should . . . be larger than if a prominent one is used. . . (H)eadings in common use are between one-tenth and one-twentieth of the height of the advertisement." (p. 42)
2. In an experimental test of contrast, "words printed in red had approximately eight times as great a chance of being noticed as . . . words printed in black." (p. 72)
3. "(A)ny background other than white makes the advertisement, as a rule, more difficult to read. The same is true of bizarre type, or unusual arrangements of words. A dead-black background often is repulsive . . . ." (p. 75)
4. "A dark shade and a light shade close together tend to make each other appear darker and lighter, respectively . . . ." (p. 76)
5. In a test of artistic-value of colors, the following preferences were seen (in descending order): men - blue, red, purple, violet, green, orange, greenish blue, bluish green, yellowish green, and yellow; women - red, blue, greenish blue, violet, green, yellow, bluish green, purple, orange, and yellowish green.
6. In a test of attention-value of colors, the following preferences were seen (in descending order): men - black, red, orange, green, blue, purple, and yellow; women - red, green, black, orange, blue, purple, and yellow; average - red,

black, green, orange, blue, purple, and yellow.

7. The illustrative-value of colors is seen in producing perspective. "Red seems nearer than blue at the same distance, and a bright object seems nearer than a dark one." (p. 79)
8. "Borders . . . increase the attention-value by their tendency to arrest eye-movement." (p. 84) However, they should "not be employed unnecessarily or act as counter-attractions." (p. 85)
9. "The pages usually designated as preferred (for attention value in magazine advertising) are:
    1. "The last outside cover page.
    2. "The first inside cover page.
    3. "The last inside cover page. . .
    4. "The page facing the first page of reading matter.
    5. "The page facing the last page of reading matter.
    6. "The page facing the first inside cover.
    7. "The page facing the last inside cover.
    8. "The page facing the table of contents." (p. 107)
10. Also concerning attention value, "the upper quarters, and particularly the right quarter on the right page, appear to have appreciably greater values than the lower quarters, particularly the lower left quarter." (p. 115)
11. In newspaper advertising, the following positions seem to have preference:
    1. "Top of column surrounded by reading. . .
    2. "Top of column next to reading. . .
    3. "Bottom of column surrounded by reading. . .
    4. "Following and alongside of reading. . .
    5. "Next to reading. . .
    6. "Women's pages. . .
    7. "2nd, 3rd, or last page. . .
    8. "Opposite editorial page. . .
    9. "First and last page of sections." (p. 126)
12. In street railway advertising, "(a)ll (cards) have an equally advantageous location. . . excep(t) . . . where cards are placed over the doors." (p. 128)
13. "(T)he number of words (in a heading) should not . . . exceed five . . . Short words are preferable to long words. A one-line . . . heading is ordinarily better . . . ." (p. 150)
14. "(F)actors which affect the legibility of print (are): (a) the type; (b) the length of the lines in print; (c) the distribution of the lines, words, and letters; (d) the background upon which the text is printed." (p. 181)
15. In several tests of legibility, the following results were obtained:

    "(I)talic text was not read as rapidly as . . . roman . . . ." (p. 182)

    "Capitals are more difficult to read than lower case (because) they are stiff, . . . have more angles and fewer curves(, and) . . . are also less common, so that the eye is not so fully accustomed to them." (p. 182)

    In a threshold test, the following order of legibility was seen for nine faces: NEWS GOTHIC, CUSHING O.S., CENTURY O.S., CENTURY EXPANDED, CHELTENHAM WIDE, SCOTCH ROMAN, BULFINCH, CASLON, and CUSHING MONOTONE.

    "Condensed and expanded faces are harder to read . . ., especially . . . in large quantities with little space between the words and lines. Expanded faces, however, are good for street car cards because of the . . . angle from which . . . seen." (p. 182-183)

    "A type face . . . with . . . few angles and corners is read most easily. The old ROMAN . . . face . . . comes nearest . . . . GERMAN print is . . .

responsible for . . . visual defects among the school children of Germany." (p. 183)

"Type smaller than ten point becomes increasingly difficult (to read) as it decreases in size." (p. 185)

"A line five or six inches in length does not look . . . inviting . . . ." (p. 186) A 2-3/4 inch long line was read at a higher rate of speed than either a 1-1/2 or 5-inch line. "In . . . long lines it is . . . difficult for the eyes, when shifting . . ., to find the beginning of the next line." (p. 187)

"The advertisement which won the prize as . . . the poorest . . . out of (a) large number . . . had . . . words of . . . text . . . arranged in step-ladder fashion from the bottom up . . . ." (p. 189)

"A white background with black type is, as a rule, the most legible combination." (p. 189) An experiment showed "a difference of 42 percent in favor of . . . black . . . on white . . . ." (p. 190)

16. The most esthetically pleasing shapes are as follows (not necessarily in order). Ratios show first the vertical and then the horizontal axes:
    - OPTICAL SQUARE: 1.00 to 1.03.
    - CIRCLE: 1.00 to 1.00.
    - DOUBLE SQUARE: 1.00 to 2.00.
    - GOLDEN RECTANGLE: 1.00 to 1.62 (approx. 5 to 8).
    - OVAL: 1.00 to 1.62.
17. "The optical center (of a rectangle) . . . is located above the actual center by approximately one-tenth of the distance from the lower border to the mathematical center. . . For example, the lower half of the letter S is slightly larger than the upper half. . . the middle bar in the letter E is slightly above the center." (p. 207-208)

An appendix depicts the following type faces:

| type face: | point size: | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CHELTENHAM | 6- | 8- | 10- | 12- | 14- | 18- | 24- | 30- | 36- | | 48- | 60- | 72- |
| CHELTENHAM BOLD | 6- | 8- | 10- | 12- | 14- | 18- | 24- | 30- | 36- | 42- | 48- | 60- | 72- |
| CHELTENHAM BOLD CONDENSED | 6- | 8- | 10- | 12- | 14- | 18- | 24- | 30- | 36- | 42- | 48- | | |
| CHELTENHAM BOLD ITALIC | 6- | 8- | 10- | 12- | 14- | 18- | 24- | 30- | 36- | | 48- | | |

(above from p. 277-281)

* * *

3338 Starch-1923
Starch, Daniel
Harvard U., Cambridge, Mass.
PRINCIPLES OF ADVERTISING
Chicago, Ill., A. W. Shaw Co., 1923, 998 p.

Problem: "This treatise has been prepared with three aims in mind. (1) to make a broad and comprehensive analysis of the fundamental problems of advertising . . .; (2) to develop . . . scientific methods in dealing with these problems; (3) to bring together . . . all available material--- . . . experience . . . and . . . data---which bear upon the problems . . . ." (p. iii)

Procedure: The following outline of contents shows the scope of the book (special emphasis is placed on those areas relating to legibility):

1. The first four, introductory, chapters concern the problems, scope, history, and development of advertising; as well as the place of advertising in business.
2. Chapters five through ten concern the human aspects of the market---specifically an analysis of the problem, methods of investigation, and sample investigations.
3. Chapters eleven through sixteen cover the analysis and selection of appeals, determination of the value of appeals, the validity of laboratory-field experiments, sample results of tests, and sex and class differences.
4. Section four, the presentation of the appeals, is covered by chapters seventeen through twenty-seven. Of these, the first four concern the analysis of problems, suggestive and argumentative advertising, and truth in advertising. Chapter twenty-one concerns headlines, "the guide-posts of advertisements," and includes (1) the mechanical and meaning aspects of criteria for judging headlines, (2) size of type for headlines, (3) length of headline, (4) experimental demonstration of the law, (5) increase in use of short headlines, (6) the magazine test, (7) location of headline, (8) form of heading, (9) stating the vital point of the advertisement, (10) blind headings, (11) objections to blind headings, (12) stimulating reading of the text, (13) using the news factor, (14) appealing to human instincts, (15) classes of display headings, (16) relative merits of different classes of headings, (17) a selling point as heading, (18) the question and the command, (19) relative frequency of use of different kinds of headings, (20) catch phrases and slogans, and (21) how to test headlines. Chapters twenty-two and -three concern illustrations and the size of advertisements. Chapter twenty-four, color, includes (1) extent of the use of color pages in magazines, newspapers, and catalogs, (2) evidence regarding effectiveness of color in advertising, (3) "pulling power" of color, (4) opinions of advertisers, (5) use of color, (6) artistic value of different colors, (7) attention value of colors, (8) illustrative value of colors, (9) test to determine the relative values of colors and the colors to be used for a specific purpose, (10) color theory, (11) the Munsell system of color notation, (12) tests to determine the validity of this theory, and (13) methods of the investigation. Chapter twenty-five, layout and typography, includes the following:

   Importance of layout. 1. Attention elements. Importance of attention factors. Laws of attracting attention: (a) The law of magnitude or intensity. Application of law of magnitude. Increase in size of display type used. The point system of measuring type. Testing the attention value of display type. How large should display lines be? (b) Law of isolation or counter-attraction. Application of the law. (c) Movement---its application to layout. Borders, eye-movement and attention. Increase in use of borders. Rules for the use of borders. Directing the movement of the eyes. (d) The principle of contrast. An experimental test of contrast. Contrast devices. Black and white contrast. Comparative values of mechanical and interest factors in securing attention. 2. Artistic elements.

Art for business' sake. Psychological effects. Artistic forms. Classes of forms and outlines. Applications in advertisements. Meaning of balance. The optical center. Location of the main features. The principle of support or stability. Representation of action. Meaning of harmony. Harmony in forms and shapes. Styles of type. 3. Comprehension factors: Type and legibility. Four main factors. The type. Type faces commonly used at the present time. Individuality in type. The distribution of letters and words. The effect of background. . . The last two chapters in this section concern trade-marks; and packages, cartons, and labels.

5. Section five, concerning advertising mediums, is covered by chapters twenty-eight through thirty-three, and includes discussions of magazines, newspapers, direct mail material, street-car cards, and posters and other miscellaneous mediums, as well as an introductory discussion of general considerations.
6. The special fields of advertising, covered by chapters thirty-four through -seven, are concerned with national, retail, foreign, and financial advertising.
7. An appendix shows samples of type faces in 6-, 8-, 10-, 12-, 14-, 18-, 24-, 30-, 36-, 42-, and 48-point sizes. Of the ones shown, CHELTENHAM BOLD, REGULAR, EXTENDED, CONDENSED, and CONDENSED ITALIC are in all the above sizes; while CHELTENHAM BOLD ITALIC is in all except the 48-point sizes; CHELTENHAM OLD STYLE in all less than 42-point sizes; CHELTENHAM OLD STYLE ITALIC in all less than 30-point sizes; and BODONI BOLD, CLOISTER BOLD, SCOTCH ROMAN, and CASLON BOLD in 24-point caps and lower case.

Result: Chapters XXI, XXIV, and XXV in part 4 (the presentation of the appeals), and the material in the appendix are of special interest to this study. The following statements extracted from these chapters (and some others as indicated) are of interest to the design of characters and their typographic environment:

1. Chapter XVIII (principles underlying suggestive advertising) - The HANDWRITING of adults shows the following characteristics: "Average inclination (from the horizontal) of l (el) . . . 65. 1 degrees. . . Average width of letters . . . 4. 33 mm." (p. 394)
2. Chapter XXI (criteria for judging headlines) - "1. The type should be large enough to set it off and secure the attention of the reader. 2. The headline should have as few (and short) words as possible (five or less) so that it may be read as quickly as possible. 3. The type and the arrangement of the words should make the reading as easy (preferably instantaneously) as possible. 4. The headline should be located where it will be seen to the best advantage (without counter-attractions and in an optically good location)." (p. 491)
3. Chapter XXI (increase in use of short headlines) - "A one-line or 'single-deck' heading is ordinarily better . . . ." (p. 497)
4. Chapter XXIV (evidence regarding effectiveness of color in advertising) - In a series of letter inquiries sent to dealers by a manufacturer of house dresses, more replies came back from the letters printed on pink paper. Next in order were those printed on gold, green, corn, and white papers.
5. Chapter XXIV (evidence regarding effectiveness of color in advertising) - "A publication can probably not carry over 15 to 20 (percent) of its space in color without reducing considerably the (overall) effect of contrast." (p. 587)
6. Chapter XXIV ("pulling power" of color) - "Although . . . a booklet illustrated by the three-color process costs four times as much as . . . in black, . . . the extra cost is clearly justified. . . (since) 'a cut in color will sometimes sell as high as 15 times as many goods . . . .' 'It has been found, for instance, that a single word in red ink increased the pulling power . . . exactly one-third. This was plainly due to the contrast . . . and would not be the case if other color printing had been in competition . . . .'" (p. 587-588)

7. Chapter XXIV (artistic value of different colors) - Several tests of color preferences showed the following (in decreasing order of agreeability): Men - blue, red, purple, violet, green, orange, greenish blue, bluish green, yellowish green, and yellow. Women - red, blue, greenish blue, violet, green, yellow, bluish green, purple, orange, yellowish green. "(T)he color preference of primitive people (is) in the following order: red, blue, green. . . (W)ith . . . children . . . the following order of preference: blue, red, yellow, and green. Yellow decreased (and green increased) . . . with the increase in age and intelligence of the child." (p. 591) Another worker "found the following order of preference (in children): Blue, red, green, yellow." (p. 591)
8. Chapter XXIV (attention value of colors) - In a rapid exposure test, the following order of colors was found for their attention value: Men - black, red, orange, green, blue, purple, and yellow. Women - red, green, black, orange, blue, purple, and yellow. Average - red, black, green, orange, blue, purple, and yellow.
9. Chapter XXIV (illustrative value of colors) - "Colors . . . aid in producing perspective. Red seems nearer than blue . . . and a bright object seems nearer than a dark one." (p. 593)
10. Chapter XXIV (tests to determine (a) the relative values of colors and (b) the colors to be used for a specific purpose) - In a test of consumer preference for single color advertisements, the following results were obtained (order of preference, 1-10):

| color | men | women | total | artists |
|---|---|---|---|---|
| purple-blue | 1 | 1 | 1 | 2 |
| blue | 2 | 3 | 2 | 7 |
| yellowish-red | 3 | 2 | 3 | 1 |
| blue-green | 5 | 4 | 4 | 5 |
| red | 6 | 6A | 5 | 6 |
| violet | 7 | 5 | 6 | 8 |
| yellow | 4 | 8 | 7 | 3 |
| green | 8 | 9 | 8 | 9 |
| orange | 9 | 6B | 9 | 4 |
| greenish-yellow | 10 | 10 | 10 | 10 |

In a test of preference for color patches taken from the above noted advertisements, the following results were obtained:

| color | men | women | total |
|---|---|---|---|
| purple-blue | 7 | 6 | 7 |
| blue | 2 | 2A | 2A |
| yellowish-red | 9 | 9 | 9 |
| blue-green | 4 | 5 | 4 |
| red | 1 | 1 | 1 |
| violet | 5A | 4 | 5 |
| yellow | 8 | 7A | 8 |
| green | 5B | 7B | 6 |
| orange | 3 | 2B | 2B |
| greenish-yellow | 10 | 10 | 10 |

In a test of preference for two-color advertisements, the following results were obtained (again, consumers vs. artists):

| color | men | women | total | artists |
|---|---|---|---|---|
| blue and yellow | 1 | 1 | 1 | 1 |
| blue and red | 2 | 2A | 2 | 2 |
| purple and yellow | 3 | 5A | 3 | 7 |
| violet and green | 5A | 4 | 4A | 3 |
| red and green (#4) | 4 | 2B | 4B | 4 |
| red and green (#9) | 5B | 5B | 6 | 10 |
| blue and orange | 7 | 7 | 7 | 8 |
| red and orange | 9 | 9 | 8 | 6 |
| purple and orange | 8 | 10 | 9A | 5 |
| green and yellow | 10 | 8 | 9B | 9 |

Patches taken from the two-color advertisements showed the following color preferences:

| color | men | women | total |
|---|---|---|---|
| blue and yellow | 2 | 2 | 2 |
| blue and red | 1 | 5A | 3 |
| purple and yellow | 8 | 3 | 5 |
| violet and green | 9 | 1 | 1 |
| red and green (#8) | 4 | 7 | 6 |
| red and green (#10) | 7 | 4 | 8 |
| purple and yellow (sic) | 5 | 9A | 7 |
| red and yellow (sic) | 6 | 9B | 9 |
| purple and orange | 3 | 5B | 4 |
| green and yellow | 10 | 8 | 10 |

"The third series . . . consisted of 10 multi-colored advertisements . . . (P)reference tests for the colors off the advertisements . . . showed the results given . . .:

| color | men | women | total | artists |
|---|---|---|---|---|
| green, blue, red | 1 | 2 | 1 | 4 |
| blue, purple, red | 3 | 1 | 2 | 6 |
| orange, blue, green | 2 | 4 | 3 | 1 |
| red, green, yellow | 4 | 3 | 4 | 8 |
| red, yellow, green | 5 | 5 | 5 | 3 |
| purple, yellow, red | 6 | 6 | 6 | 5 |
| violet, yellow, green | 7 | 7 | 7 | 2 |
| green, blue, brown | 8 | 8 | 8 | 7 |
| red, blue, yellow | 9 | 9 | 9 | 10 |
| yellow, red, green | 10 | 10 | 10 | 9 |

"The results showed a fairly decided preference (in the consumers) for complementary . . . colors . . . . The preferences of the artists differ(ed) . . . materially . . . . The . . . inference is that the consumer . . . is a more reliable index of color preferences . . . ." (quoted material and tables in the preceding from p. 599-605)

11. Chapter XXV (the importance of layout) - "'In . . . power to attract the reader's eye as the line of vision enters a page there are various methods . . . . It can be done with extraordinarily large black bars at the top and bottom; with a heavy black border; with a circle; a curve; anything that will intercept the left-to-right path of vision and carry it to the desired point . . . . White space to the left of the type matter has the same effect. . . Setting the headline in "reverse"---white letters on a black background---has 50 (percent) greater power to attract the eye than plain black type. . . To be optically correct (the center display)

. . . should be two-thirds to three-fourths the length of the advertisement above its base. . . It is due to the way the average reader holds a magazine or newspaper. . . When the type gets down to 6-point it becomes hard to read if the lines are 5 or 6 inches in length. . . If the headline is set in plain type, then it should be surrounded with 1-1/2 to 2 inches of white space . . . to allow it to stick out from the surrounding type matter.'*'' (p. 609-610) Diagonal lines, panels, arrows, and check marks are other ways of attracting attention to specific parts of a layout.

12. Chapter XXV (laws of attracting attention) - "To demonstrate the . . . law (of magnitude or intensity), an experiment was performed . . . (which showed that) words printed in large type had about five times as much attention value as the words printed in small type . . . ." (p. 615-616)
13. Chapter XXV (the point system of measuring type) - "About 1886 the American Type Founders Union established what became known as the Point System. . . The sizes of various kinds of type formerly used are designated according to the point system:

    4-point equals Diamond
    5-point equals Agate or Pearl
    5-1/2-point equals Ruby
    6-point equals Nonpareil
    7-point equals Minion
    8-point equals Brevier
    9-point equals Bourgeois
    10-point equals Long Primer
    11-point equals Small Pica
    12-point equals Pica
    14-point equals English
    18-point equals Great Primer." (p. 618)

    Other typographic conventions are also given. The more important of these are the following:

    "Seventy-two points equal one inch. . .
    "(A)gate . . . is the standard . . . of advertising space. . .
    "(U)sually 2-point leads are placed between the lines." (p. 618)
    Twelve points equal one pica, hence six picas equal one inch.
14. Chapter XXV (testing the attention value of display type) - Experiments showed that "in general the attention value . . . is closely proportional to the size of the letters." (p. 621)
15. Chapter XXV (how large should display lines be?) - "(T)he headings in common use are between one-tenth and one-twentieth of the height of the advertisement." (p. 622)
16. Chapter XXV (application of the principle of isolation or counter-attraction) - "As a general rule, subheadings should not exceed one-third the size of the main display line." (p. 625)
17. Chapter XXV (movement---its application to layout) - "(L)ines which are at right angles to the movement of the eyes tend to arrest the movement and cause the eyes either to stop or to follow in the direction of the lines." (p. 627)
18. Chapter XXV (borders, eye-movement and attention) - "Borders have four . . . distinct uses: (1) . . . increase the attention value . . .; (2) . . . lend unity, compactness, and individuality; (3) . . . serve to separate . . .; (4) . . . add a decorative and illustrative value . . . ." (p. 627)

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* - Printers' Ink, January 25, 1912, p. 10.

19. Chapter XXV (rules for the use of borders) - "(A) plain, simple border is preferable to a fancy, elaborate border. . . unless there are special reasons for (the ornamental one) . . . ." (p. 631)
20. Chapter XXV (the principle of contrast) - In an experimental test of contrast, "words printed in red had approximately eight times as great a chance of being noticed as . . . words printed in black." (p. 635)
21. Chapter XXV (contrast devices) - "Some of the devices . . . in common use are the following: Black, gray, or colored backgrounds; large amounts of vacant white space; odd shapes, circles, ovals, curves, diagonal lines; bizarre type; . . . odd borders; unusual arrangements of type and words." (p. 636) However, the use of any of these may have other detrimental effects that outbalance their benefit as a contrast device.
22. Chapter XXV (classes of forms and outlines) - "The chief . . . forms and outline (are) . . . as follows:" (p. 645)
    a. The OPTICAL SQUARE - sides in a ratio of 1.00 to 1.03, vertical to horizontal.
    b. The CIRCLE - diameters in a ratio of 1.00 to 1.00, vertical to horizontal.
    c. The DOUBLE SQUARE - sides in a ratio of 1.00 to 2.00.
    d. The GOLDEN SECTION RECTANGLE - sides in a ratio of 1.00 to 1.62, or approximately 5 to 8.
    e. The OVAL - axes in a ratio of 1.00 to 1.62.
23. Chapter XXV (the optical center) - ". . . is located above the actual center by approximately one-tenth of the distance from the lower border to the mathematical center. . . For example, the lower half of the letter S is slightly larger than the upper half. . . (A)lso the middle bar in the letter E is slightly above center." (p. 649-650)
24. Chapter XXV (location of the main feature) - "(T)he best positions are as follows, in the order of preference:
    a. "At the optical center.
    b. "At the upper division point of the 'golden proportion.' That is, at the point so located that the upper area and the lower area maintain the ratio of 1 to 1.62. . .
    c. "At the lower division point of the 'golden proportion.'
    d. "Near the extreme top.
    e. "Near extreme bottom." (p. 651)
25. Chapter XXV (the principle of support or stability) - "If we have a weight, say . . . a block of heavy type, in one position, it must be placed above the center of support. If it is placed at one side . . . it must be counter-balanced by a weight on the opposite side." (p. 651)
26. Chapter XXV (harmony in forms and shapes) - "(C)urves and curvilinear forms . . .; straight lines and rectangular forms go well together." (p. 656)
27. Chapter XXV (tone) - "(T)oo much dead black . . . give(s) a depressing effect." (p. 656)
28. Chapter XXV (styles of type) - "Fancy or special type should be used only when it adds to . . . effectiveness . . . in giving . . . distinctiveness or greater aesthetic effect. . . As a rule not more than two different (type) faces should be allowed (in the same text); unless they are closely related . . . ." (p. 656)
29. Chapter XXV (comprehension factors: type and legibility) - "There are four main factors which affect the legibility of print: (a) The type; (b) the length of the lines in print; (c) the distribution of the lines, words, and letters; (d) the background upon which the text is printed." (p. 657)
30. Chapter XXV (the style or face of the type) - In an experimental test, it was shown that "italic text (is) not read as rapidly as . . . roman text." (p. 658) Another experiment showed "a difference of 10 (percent) in favor of . . . lower-case type" (p. 658) when compared with the reading speed of all capitals. In a

threshold experiment, the following rank was seen for the "legibility" of nine type faces: NEWS GOTHIC, CUSHING OLD STYLE, CENTURY OLD STYLE, CENTURY EXPANDED, CHELTENHAM WIDE, SCOTCH ROMAN, BULFINCH, CASLON, and CUSHING MONOTONE. "Condensed and expanded faces are harder to read than the ordinary widths . . . Expanded faces . . . are good for street-car cards because of the oblique angle from which they are generally seen. . . (T)ype . . . constructed on plain, simple lines with relatively few angles and corners is read most easily. The old ROMAN . . . face . . . comes nearest . . . and is generally conceded to be the most legible . . . (T)he angular and difficult character of the GERMAN print is . . . responsible for the prevalence of visual defects among the school children of Germany. . . Fancy and unusual types . . . contain too many nooks and corners, too many angles and curly-cues. . . (and) should be avoided unless there are good reasons for using it." (p. 660)

31. Chapter XXV (type faces commonly used at the present time) - "BODONI, CASLON, and CHELTENHAM . . . are used most commonly because experience and psychological experiment have shown that the small, plain, graceful type face is, on the whole, the most legible as well as the most pleasing." (p. 662)
32. Chapter XXV (the size of the type) - "Type smaller than 10 point becomes increasingly difficult (to read) as it decreases in size." (p. 663)
33. Chapter XXV (length of the line of print) - "A line five or six inches in length does not look . . . inviting . . . A long line printed in large type is easier to read than the same line in smaller type." (p. 663) An experiment involving the reading of lines 1-1/2, 2-3/4, and 5 inches long resulted in the ascertaining that "a certain optimum length of line (is) somewhere in the neighborhood of 3 inches. . . The average newspaper line is about 2-1/4 inches and the average magazine line is about 2-1/2 inches long. . . The eyes, in reading, . . . take . . . glimpses at intervals of three to five words. . . In lines of moderate length the subject-matter in adjoining lines is more closely related than in long lines. . . (p. 666) In very long lines it is . . . difficult . . . when shifting (the eyes) . . ., to find the beginning of the next line." (p. 668)
34. Chapter XXV (the distribution of letters and words) - "(U)nusual arrangements and distributions of letters and words" (p. 668) should be avoided since they tend to "make an advertisement nothing short of an optical puzzle." (p. 668)
35. Chapter XXV (the effect of background) - In an experiment, black type on a white background was found to read 42 percent faster than white type on a dark gray background.

A rather lengthy dissertation concerning preferred space in different types of magazines (Chapter XXIX) may have some application to the layout of printed material.

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3299 Swartz-1961

Swartz, W. F.
Martin Co., Baltimore, Md.
REVIEW OF THE LITERATURE CONCERNING DESIGN OF DIGITS
Memorandum rept. 61-1, 8 Feb 61, 20 p.
In AIR FORCE FLIGHT CONTROL AND FLIGHT DISPLAY INTEGRATION PROGRAM: MARTIN HUMAN ENGINEERING MEMORANDUM REPORTS, 1961, Engineering rept. no. 12, 191, Dec 61, lv.
AD-273 321

Problem: Review the "literature concerning the design and construction of digits . . . (in) an effort to optimize digit design for moving tape instruments." (p. 1)

Procedure: Twelve critical typographical and environmental parameters have been seen

(in the experimental literature) to affect significantly subjects' performance (criteria used have been speed, accuracy, maximum reading distance, "or some other score" (p. 2)) either directly or by complex interactions. These parameters are digit (which one of the ten numeric characters), stroke-width, digit-width, style, illumination (of the viewing surface), brightness (reflected from the surface), viewing angle, response mode (of the subject), subject, contrast relation (direction), arrangement-of-numerals (grouping), and exposure time. The styles investigated are Arabic and those that are novel by "grade school" (p. 3) standards. The Arabic included AND 10400 (characterized by open 4, exaggerated 6 and 9 loops, and flat stubby 3), MS 33558 (similar), BERGER (for auto license plates and characterized by horizontal, vertical, and 45° angle lines), MACKWORTH (for distant recognition and similar to AND 10400 ), AMEL ( AND 10400 plus BERGER ), CRAIK (marked differences in size between upper and lower portions of 3, 6, 8, and 9), MODERN (uniform in height and line position), OLD STYLE (0, 1, and 2 are small in relation to others), LEROY (hand lettering having closed loops and curved stems), and ORDNANCE (some digits extend above or below the line). The NOVEL included straight line matrices, dot codes, counting lines, dot positions, line indications, ellipse-axis ratios, color coding, LANSDELL , and ROMAN NUMERALS. Discussed next are the results of sixteen experiments* that ascertained the effects of various critical parameters and their interactions on the legibility of both Arabic and novel digits.

Result: Three factors prohibiting extrapolation of the results of previous work to the design of digits for moving tape instruments "are (1) the interaction of critical parameters (and the inability to generalize therefrom), (2) inter-subject differences (particularly with respect to subject/critical parameter interaction), and (3) the methodological problem (in the prostitution of results because of poor methodology and the almost non-existent relation of experiment to the actual use of the digits)." (p. 14) Hence, while "the literature has pointed out the parameter . . . of interest . . ., it seems . . . naive to base the design (of digits for moving tape) upon past . . . results." (p. 18)

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* Experiments were performed by various investigators, whose work may be found elsewhere in this volume as Alluisi-1957, Alluisi-1958, Atkinson-1952, Brown-1951, Cohen-1953, Colgate-(1955) (which includes Reinwald's 1953 work), Foley-1956, Kuntz-1950, Lansdell-1954, Loucks-1944c, Perry-1952, Schapiro-1952, and Soar-1955a (which is a later publication of Soar's 1952 thesis). Work not shown herein was done by S.C. McLaughlin, Jr., Configuration and stroke-width in numeral legibility, Unpublished thesis, Tufts College, Medford, Mass., 1948; and also by M.A. Tinker, The relative legibility of modern and old style numerals, Journal of Experimental Psychology, v. 13 (1930) 453-461.

* * *

2125 Tinker-1944

Tinker, Miles A.
Minnesota U., Minneapolis

CRITERIA FOR DETERMINING THE READABILITY OF TYPE FACES

Journal of Educational Psychology, 35:7
(October 1944) 385-396

Problem: Measure the "visibility of text" for ten type faces, and compare the results with "the perceptibility at a distance, and the speed of reading of materials printed in (the same) ten type faces. . ." (p. 386) as measured in previous experimentation.

Procedure: The ten book type faces utilized were: SCOTCH ROMAN, GARAMONT, ANTIQUE, BODONI, OLD STYLE, CASLON OLD STYLE, CHELTENHAM, KABEL LIGHT, AMERICAN TYPEWRITER, and CLOISTER BLACK (OLD ENGLISH). "In the . . . study, thirty five-letter words were cut from the text for each type face and each word mounted at the center of a four-by-six white index card. . . (M)easurements were made with the Luckiesh-Moss Visibility Meter. . . in a light laboratory with ten-foot-candles of general illumination. . . The . . . meter was mounted at a constant distance of fifteen inches from the test card which was held on a slanting reading stand." (p. 386) Each of thirty-six university student subjects (having normal vision) "slowly rotated . . . filters in the apparatus until the word could be apprehended." (p. 386) Subjects were divided, four each, into nine groups (the tenth face, SCOTCH ROMAN, was the control for each group). All faces "were printed in ten-point type . . . on enamel paper stock. Illustrations of the type faces are shown in Paterson and Tinker (J. Appl. Psychol., 1932, 16, 605-613)." (p. 386)

Result: The following table shows a "(c)omparison of (v)isibility, (p)erceptibility at (d)istance, (s)peed of (r)eading, and (r)eader (o)pinions of legibility for (t)en (t)ype faces": (p. 391)

| Type Face Comparison: | Visibility | | Perceptibility | | Speed of Reading | | Reader Opinions | |
|---|---|---|---|---|---|---|---|---|
| SCOTCH ROMAN Versus | percent difference | rank | percent difference | rank | percent difference | rank | mean rank | rank |
| ANTIQUE | +56.3 | 1 | -14.8 | 3 | -0.2 | 3 | 2.4 | 2 |
| CHELTENHAM | +38.6 | 2 | -22.2 | 2 | -2.5 | 8 | 2.3 | 1 |
| AMERICAN TYPEWRITER | +36.5 | 3 | -37.7 | 1 | -5.1 | 9 | 5.5 | 6 |
| CLOISTER BLACK | +25.0 | 4 | +2.3 | 10 | -16.5 | 10 | 9.8 | 10 |
| BODONI | +19.5 | 5 | -4.6 | 7 | -1.1 | 4.5 | 4.2 | 3 |
| GARAMONT | +16.9 | 6 | -6.8 | 6 | +0.5 | 1 | 5.4 | 5 |
| OLD STYLE | +15.8 | 7 | -11.4 | 4 | -1.1 | 4.5 | 4.6 | 4 |
| CASLON OLD STYLE | +11.1 | 8 | -7.9 | 5 | -1.3 | 6 | 6.4 | 8 |
| KABEL LIGHT | +8.2 | 9 | +0.1 | 9 | -2.3 | 7 | 8.2 | 9 |
| SCOTCH ROMAN | 0.0 | 10 | 0.0 | 8 | 0.0 | 2 | 6.2 | 7 |

(above from p. 391)

"All differences for the visibility data are statistically significant; for perceptibility data, differences of six per cent and greater are significant; and for speed of reading data, differences of five per cent and greater are significant. For perceptibility, minus differences mean better perceptibility. . . The ranks for judged legibility correspond more closely to visibility and perceptibility ranks than to speed of reading ranks. The correlations follow:

| | | |
|---|---|---|
| Visibility | vs. judged legibility | +.58 |
| Perceptibility | vs. judged legibility | +.67 |
| Speed of reading | vs. judged legibility | +.33 |

"Of the techniques employed in this (and previous) stud(ies), speed of reading appears to provide the best possibilities as a measure of readability. . . There are, however, certain situations where visibility and perceptibility are obviously factors in readability: (1) For relatively small type sizes, as six and seven point, visibility and perceptibility reduces readability. (2) Variation in brightness contrast between print and background affects readability and this is due to variations in perceptibility." (p. 391-393) Finally, the following conclusions were summarized:

1. "Although there were marked individual differences present, the trends from subject to subject were consistent.
2. "Differences between the type faces are more striking in terms of visibility, perceptibility and reader preferences than for speed of reading.
3. "Measures of visibility and perceptibility corresponded moderately well except for CLOISTER BLACK type face. Neither of these measures agrees with speed of reading. Readers preferences agree best with perceptibility at a distance.

"Analysis of the results, taking account of the normal reading situation, perceptual habits in reading and practicality, indicate that speed of reading when adequately controlled is the most valid of (those discussed) as a measure of readability." (p. 395)

* * *

3352 Tinker-1945

Tinker, Miles A.

Minnesota U., Minneapolis

RELIABILITY OF BLINKING FREQUENCY EMPLOYED AS A MEASURE OF READABILITY

Journal of Experimental Psychology, 35:5
(October 1945) 418-424, 5 refs.

Problem: "(D)etermine under controlled experimental conditions the . . . reliability or consistency of response for blink-rates . . . from one reading period to another. . . as a measure of readability." (p. 418 & 423)

Procedure: "The experiment was carried out in a light laboratory with 10 foot-candles of well diffused illumination. Two studies were completed. In Study I, 74 university students . . . read in Dibble's Strenuous Americans. . . printed in 11 point type with 2 point leading in a 22 pica line width on rough surfaced paper. In Study II (64 students read) . . . material consist(ing) of Winkler's Morgan the Magnificent. . . printed in 12 point type with 2 point leading in a 23 pica line width on rough surfaced paper. . . The textual material was placed on an inclined stand at the normal reading distance from the (subject) ---about 14 (inches). . . Direct observation was employed. . . in counting eye blinks . . . Each (subject) . . . was told to read with comprehension and at his normal rate . . ." (p. 418) for 30 minutes. "The number of pages read was recorded." (p. 419)

Result: "Trends in the two sets of data were approximately the same. The mean blink-rate tended to increase on successive periods of reading and the coefficients of variation were high. . . The blink-rate consistency was fairly high from one five-(minute) reading period to the next . . . (median reliability coefficient = about .88). The trend was about

the same for adjacent 10-(minute) periods . . . When an interval of 20,(minutes) of reading intervene(d), . . . the reliability drop(ped) to about .50 for blink-rates during five (minutes) of reading. For 10-(minute) periods . . ., the coefficient drop(ped) to about .65. . . When individual data (were) considered it (was) found that, as reading (went) on, the blink-rates of some readers increase(d), of others decrease(d), and of still others show(ed) no change. During successive . . . periods . . ., individual blink-rates . . . oscillate(d) markedly. . . Th(e) data reveal(ed) highly satisfactory reliability where group comparisons of means are involved for blink-rates recorded during successive adjacent periods of reading. . . Since the reliability of the blink-rates . . . increase(d) somewhat for 10-(minute) periods, it seems best to record blinks for 10 rather than for five (minutes) when a period of reading intervenes between the periods compared. . . The next step is to determine the validity of blink-rates as a measure of readability." (p. 423-424)

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3343 Tinker-1946

Tinker, Miles A.
Minnesota U., Minneapolis
VALIDITY OF FREQUENCY OF BLINKING AS A CRITERION OF READABILITY
Journal of Experimental Psychology, 36:5 (October 1946) 453-460, 24 refs.

Problem: Compare blink frequency in "(t)he reading of text in roman lower case . . . with the reading of text in all-capitals . . ." (p. 453) in order to ascertain "the validity of blink frequency as a criterion of readability." (p. 453)

Procedure: "Sixty university students . . . rea(d) for two experimental sessions. . . in a light laboratory (under) 10 foot-candles of well diffused illumination. . . The textual material (placed on an inclined stand at about 14 inches from the subject) consisted of Forms I and II (equivalent) of Tinker's Speed of Reading Test. . . Form I was printed in 10-point lower case EXCELSIOR type with 2-point leading in a 20-pica line width on eggshell paper stock." (p. 453-454) Form II differed only by being in all-capitals. Subjects' task was to cross-out (orally) the one word of 30, in each of 450 items, that spoiled the meaning of the item. This was done in order "to show that the material ha(d) been read and comprehended. . . The direct method of observing and counting eye blinks . . . was employed. Speed of reading in terms of number of items read correctly, as well as number of blinks, was recorded." (p. 454)

Result: "There was no significant difference in rate of blinking while reading text in all-capitals in comparison with lower case. . . In every comparison made, text in all-

capitals was read significantly slower than text in lower case. The percent retardation in speed of reading ranged from 9.53 to 19.01. . . Analysis of the data in this experiment plus consideration of evidence from other studies indicate(d) that the frequency of blinking is an unsatisfactory criterion of readability of print. . . The data (also) furnish(ed) additional evidence that rate of reading is a fairly adequate index of readability." (sic) (p. 459)

* * *

3325 Tinker-1948a

Tinker, M. A.

Minnesota U., Minneapolis

READABILITY OF BOOK PRINT AND NEWSPRINT IN TERMS OF BLINK-RATE

Journal of Educational Psychology, 39:1

(January 1948) 35-39, 9 refs.

Problem: "The purpose of this study is to check the rate of blinking as a criterion of readability by comparing blink rate while reading book print and newsprint. . . (p. 39) The . . . experiment aims to duplicate the experimental conditions specified by Luckiesh in his work." (p. 35)

Procedure: "The experiment was carried out in a light laboratory with 10 foot-candles of well diffused illumination. Sixty university students served as readers for two experimental sessions each. The reading material was placed on an inclined stand at the normal reading distance . . ., about fourteen inches. . . The book print was . . . (Winkler's Morgan the Magnificent) set in twelve-point type with two point leading in a twenty-three pica line width on a good quality of Matt-white paper. This . . . arrangement . . . is optimal . . . For the newsprint material, stories of general interest but unemotional in character were cut from . . . the Mankato (Minnesota) Free Press, and mounted on cardboards. The text was set in seven-point type with one-point leading in an eleven and one-half pica line width on regular newsprint paper stock. . . (T)his approximates the general trend in newspaper typography. . . (and) is optimal for seven-point newsprint. . . The direct method of observing and counting eye blinks by a skilled experimenter was employed. . . The subjects read for five minutes on each kind of material . . . ." (p. 36-37)

Result: "All requirements specified by Luckiesh for satisfactory use of the blink technique were fulfilled. . . Significantly fewer blinks were employed for reading the newsprint. Since other . . . evidence indicates that newsprint is less readable, the blink technique appears not to be valid as a measure of ease of seeing. Further checking of the validity of the blink technique is needed." (p. 39)

* * *

3365 Tinker-1948b

Tinker, Miles A.
Minnesota U., Minneapolis

EFFECT OF VIBRATION UPON READING

American Journal of Psychology, 61:3 (July 1948)
386-390

Problem: "(S)tudy the effect of vibration of textual material on speed of perception in reading." (p. 390)

Procedure: "The experiment was carried out in a light laboratory with 16 foot-candles of well diffused illumination. Two groups (control and test), each consisting of 69 students, served as readers. . . The textual material consisted of Forms I and II (equivalent) of Tinker's Speed of Reading Test. . . Both forms were printed in 10-point EXCELSIOR type with two-point leading in a 20 pica line-width on eggshell paper stock." (p. 387) Vibration was introduced by means of an apparatus attached to an inclined reading table. "The extent of the vibration was 1/16 (inch) and there were 5 cycles of movement per (second). This approximates the vibration of one's book while riding on a fast train. . . (Subjects) in the control group read Form I and . . . II of the test with the copy stationary but with the noise of the apparatus persent (sic). In the experimental group, the (subjects) read Form I with stationary copy and noise; Form II with vibrating copy (and, of course, noise)." (p. 387) Subjects responded orally throughout the experiment (giving the word that spoiled the meaning of the item). "Every (subject) read for 10 (minutes) on each form of the test, but the number of items completed at the end of every 5-(minute) period of reading were recorded. . . (p. 388) Score was in terms of the number of items, each consisting of 30 words, read by (a subject)." (p. 387)

Result: The "differences indicate, therefore, that vibration of text reduces speed of perception in reading by a significant amount (about five percent). Here is further evidence that rate of reading, when measured in a valid manner, is a fairly satisfactory criterion of readability of print.*. . It is well known that people ordinarily read much slower than they can read. . . (especially) when there is no check on comprehension. In such . . . situation(s), non-optimal factors such as print of (sic) poor readability are apt not to influence the rate of reading. . . Except with extremes, it is not a question of not being able to discriminate accurately, but of how promptly the discrimination can be made when the lighting or the print is other than optimal. . . (T)here is also the question of expenditure of energy but as yet we have no satisfactory measure of this." (p. 389-390) In conclusion, "(w)hen a variable reduces significantly rate of perception in reading, it would seem justifiable to conclude that there is a real difference in readability manifested." (p. 390)

* - "The situation is about as follows: (1) speed of reading as used by Tinker and Paterson is a fairly sensitive criterion of the readability of print. (2) Speed of reading as used by Luckiesh and by Luckiesh and Moss is not an adequate criterion of the readability

of print. Tinker and Paterson employ standardized reading tests and maintain experimental controls. Luckiesh and Moss use no standardized test-material and make no check on the comprehension of what is supposedly read. The reader must decide which of the two kinds of experimentation is more adequate for measuring the effect of illumination variation, typographical changes, vibration of text, etc., upon speed of perception in reading, or readability (sic) of print." (p. 389)

* * *

3358 Tinker-1948c

Tinker, Miles A.

Minnesota U., Minneapolis

CUMULATIVE EFFECT OF MARGINAL CONDITIONS

UPON RATE OF PERCEPTION IN READING

Journal of Applied Psychology, 32:5

(October 1948) 537-540, 2 refs.

Problem: "(I)nvestigate the effect upon speed of perception in reading of combining three marginal conditions: illumination intensity, type form and type size." (p. 540)

Procedure: Two groups (control and experiment) of 83 subjects each were tested (2 subjects at a time) on Forms I and II of the Tinker Speed of Reading Test* under the following typographical and environmental conditions (for the control group, both Forms I and II were under "standard" conditions, while, for the experimental group, Form II was under "marginal" conditions):

| conditions | standard | marginal |
|---|---|---|
| illumination intensity (well-diffused) | 25 foot-candles | 3 foot-candles |
| type form | roman | italic |
| type size | 10-point | 8-point |
| type face | EXCELSIOR | EXCELSIOR |
| leading | 2-point | 1-point |
| line-width | 20-pica | 12-pica |
| paper | eggshell | eggshell |

Result: "When employed as a single variable (in previous experimentation), neither 8 point type, italic type form, nor reading under 3 foot-candles retard(ed) speed of reading significantly." (p. 540) However, a combination of the three together "retarded speed of perception in reading by 10.4 per cent in comparison with reading 10 point Roman type under 25 foot-candles. . . To maintain a hygienic visual environment, therefore, it is important not to employ marginal (critical) levels of illumination. . . where the details to be discriminated are also marginal." (p. 540)

* - "In each form there are 450 paragraphs (items) of 30 words each. As a check on comprehension, the reader crosses out the one word that spoils the meaning in each item. The two forms are approximately equival(e)nt." (p. 537-538)

* * *

Tinker-1952

3366

Tinker, Miles A.
Minnesota U., Minneapolis

THE EFFECT OF INTENSITY OF ILLUMINATION UPON SPEED OF READING SIX-POINT ITALIC PRINT

American Journal of Psychology, 65:4
(October 1952) 600-602, 5 refs.

Problem: "(I)nvestigate the relation between level of illumination and speed of reading 6-(point) italic print." (p. 600)

Procedure: "The experiment was conducted in a laboratory which provided indirect, well-diffused incandescent illumination. The (subjects) . . . were 285 sophomores at the (u)niversity. . . divided into five groups, one control and four experimental . . . (p. 601) (R)eading material consisted of Forms I and II of Tinker's Speed of Reading Test. . . (p. 600) Form I, the standard, was printed in 10-(point) EXCELSIOR type face, Roman, 2-(point) leading, 20 pica line-width on eggshell paper stock. Form II, for Group I (control), was typographically the same . . . . For all other groups, Form II was printed in 6-(point) EXCELSIOR type face, italic, 1-(point) leading, 12 pica line-width on eggshell . . .. Form I was always read under 25 (foot-candles)." (p. 602) Form II was read under 1, 10, 25, and 50 foot-candles by Groups II through V, respectively.

Result: "As illumination intensity . . . increased from 1 to 25 (foot-candles), speed of reading 6-(point) italic print increase(d) significantly. Then there (was) a further slight but non-significant gain as the intensity (was) raised from 25 to 50 (foot-candles). It would appear that the critical level . . . is somewhere between 10 and 25 (foot-candles). . . (and) closer to 25 than 10. If 10 to 15 (foot-candles) are added . . . to provide a margin of safety, the intensity desirable . . . becomes 30 to 40 (foot-candles). There is nothing in (the) data which suggests that higher intensities are needed for the optimal perception of this type." (p. 602) Also, interestingly enough, "(t)he difference . . . in Group IV represents an 8 (percent) loss in speed of reading as a function of type-size alone . . . ." (p. 601) In connection with this, the results of previous work indicate that "the deleterious effects upon speed of perception from reducing size of type and from employing italic rather than Roman type are cumulative. This trend is similar to the cumulative effect of certain marginal conditions (variations in illumination and typography) upon rate of perception in reading discovered in (another) previous study." (p. 601-602)

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2729 Tinker-1953

Tinker, Miles A.

Minnesota U., Minneapolis

EFFECT OF VIBRATION UPON SPEED OF PERCEPTION WHILE READING SIX POINT PRINT

Journal of Educational Research, 46:6 (February 1953) 459-464, 5 refs.

Problem: "(I)nvestigate the effect of vibration upon speed of perception while reading material printed in six point Roman and six point italic type." (p. 459)

Procedure: "The experiment was carried out in a light laboratory with 25 foot-candles of well-diffused illumination. . . (p. 459) A control (69 university students) and three experimental (60 students each) groups (of subjects) were employed. . . (p. 463) The textual material consisted of Forms I and II of Tinker's Speed of Reading Test. . . Form I, the standard, was printed in 10 point Roman, EXCELSIOR type face with two point leading in a 20 pica line width on eggshell paper stock. . . (,) an optimal typographical arrangement . . . . In Group I, the control group, Form II was typographically identical with Form I. In Groups II and III, Form II was printed in six point Roman, EXCELSIOR type face with one point leading in a 12 pica line width on eggshell paper stock. And in Group IV, Form II was printed in six point italic," (p. 459-460) with other parameters the same as with Form II for Groups II and III. Vibration, at a movement of 1/16-inch and 5 cycles per second (approximates that in a fast train), was introduced by means of a motor attached to an inclined reading table. The noise of the motor was heard by the subject whether reading was done with or without vibration. Subjects in Groups I and II read both forms with the copy stationary. Subjects in Groups III and IV read Form I with the copy stationary and Form II with vibration.

Result: "In comparison with 10 point type, six point type was read 8.49 percent slower; six point with vibration, 10.99 percent slower; and six point italic with vibration, 14.21 percent slower. Vibration (alone) reduced speed of reading six point type by 2.5 percent, and six point italics by 5.72 percent." (p. 463) These differences are all significant. In addition, the results of previous work compared with this experiment show that "(v)ibration has less effect upon speed of reading six . . . than upon 10 point type (2.5 vs. 5.19 percent) except when the six point type is printed in italics." (p. 463) In conclusion, it is stated that "(t)he effects of non-optimal conditions are cumulative in reducing speed of perception in reading. The influence of small type, vibration and use of italics combine to produce a relatively large drop in speed of perception." (p. 463)

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3326 Tinker-1954

Tinker, Miles A.
Minnesota U., Minneapolis

EFFECT OF SLANTED TEXT UPON THE READABILITY OF PRINT

Journal of Educational Psychology, 45:5
(May 1954) 287-291, 2 refs.

Problem: "In . . . books (where) the printed material does not lie flat . . . (t)o what degree does this condition interfere with easy and rapid perception in reading? . . The specific problem . . . is to investigate changes that occur in speed of reading and in visibility of words when the reading copy is slanted away from the eyes at different angles." (p. 287)

Procedure: "(O)ne hundred and eighty (university student) subjects. . . (read m)aterial slanted at forty-five and at sixty degrees (in) compar(ison) with flat copy. . . (p. 291) The reading material consisted of Forms I and II of Tinker's Speed of Reading Test. In each form there (were) four hundred and fifty items of thirty words each. . . The two forms . . . were printed in ten-point EXCELSIOR type in a twenty pica line width with two-point leading on eggshell paper stock. . . For the visibility measurements, thirty five-letter words were cut from the test and pasted on white cards, one word per card. All words used (were) within the five hundred most familiar . . . The experiment was conducted in . . . twenty-five foot-candles of indirect, well-diffused incandescent illumination. . . Visibility measurements were made with the Luckiesh-Moss Visibility Meter." (p. 288-289)

Result: "Speed of reading was retarded 5.7 per cent by the forty-five-degree slant, and 16.4 per cent by the sixty-degree slant." (p. 291) These differences were highly significant. "Visibility of word forms was reduced 31.3 per cent by the forty-five- . . ., and 48.4 per cent by the sixty-degree slant. . . (p. 291) (T)hese differences (were also) highly significant . . . The role of accommodation changes cannot be determined from these results. . . It is suggested that a major portion of the retardation in reading speed is due to the reduced visibility of the words. . . These results have a bearing upon printing and binding of large books and bound journals where there tends to be considerable curvature of the lines of print near the inner margin. To avoid the deleterious effects of this . . ., it is suggested that large books and journals should be printed with a much wider inner margin." (p. 290-291)

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2731 Tinker-1955

Tinker, Miles A.

Minnesota U., Minneapolis

PROLONGED READING TASKS IN VISUAL RESEARCH

Journal of Applied Psychology, 39:6

(December 1955) 444-446, 5 refs.

Problem: "(D)emonstrate the usefulness of prolonged periods of reading in studying the effects on speed of perception in reading varying typographical arrangements." (p. 445)

Procedure: "In the first experiment Form I (of the speed of reading test) was set in regular (roman) 10-point EXCELSIOR type face with 2-point leading in a 20-pica line width on eggshell paper stock. Form II was the same typographically except that italic rather than roman type was used. Another copy of Form II was also printed exactly the same as Form I. The 192 university sophomore subjects were tested in . . . groups of about 32 each . . . In the second experiment . . . (,) Forms I and II were identical and printed in roman (upper- and) lower-case type for the control group . . . . In (another group), . . . Form II was typographically the same as Form I except that it was printed in all-capitals. There were 127 subjects . . . (university sophomores) in each test group, 254 in all. They were tested . . . in small classroom groups of about 32." (p. 444)

Result: "Reading periods of 10 minutes or more produced a significant retardation in reading italic in comparison with roman print. With a reading period of 1-3/4 minutes in an earlier experiment the retardation was not significant. . . Retardation in speed of reading all-capital material in comparison with (upper- and lower-case) roman print was large and approximately the same irrespective of the length of the reading period within the limits of 4 to 16 minutes. Approximately the same retardation was found with a time limit of 1-3/4 minutes in an earlier experiment." (p. 445) Thus, in general, it was ascertained that "(m)easuring speed of perception in reading is a relatively sensitive technique for use in typographical studies when prolonged periods of reading are employed." (p. 445)

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2732 Tinker-1957

Tinker, Miles A.

Minnesota U., Minneapolis

EFFECT OF CURVED TEXT UPON READABILITY OF PRINT

Journal of Applied Psychology, 41:4

(August 1957) 218-221

Problem: "(I)nvestigate changes that occur in speed of reading and in visibility of words when the reading copy is curved. . . (as, for example,) near the inner or gutter margin

where the pages are bound." (p. 218)

Procedure: "Traditional practice is to have (the) inner margin narrowest . . . . In . . . a typical journal page the widths of margin are: inner, 12/16 inch; top, 12/16 inch; outside, 1-2/16 inches; and bottom, 1-4/16 inches. In a large book on typographical practice the margins run: inner, 11/16 inch; top, 11/16 inch; outside, 1 inch; and bottom, 1-1/2 inches. Use of such narrow inner margins results in appreciable curvature of about one-third of the line of print in single column printing and up to four-fifths of the line in multiple column printing for the column next to the bound edge." (p. 218) In the material tested, "(t)he effect from distortions of letter and word forms on ease of perceiving (was) measured in terms of visibility of selected words. . . The reading material consisted of Forms A and B of the Chapman-Cook Speed of Reading Test. . . (printed in) 10-point SCOTCH ROMAN . . . with 2-point leading in a 19-pica line width on eggshell paper stock. . . (from which) 20 five-letter words (were) cut . . . (and) mounted on . . . index card(s). . . (p. 218) (I)n a light laboratory with 25 footcandles of well diffused indirect illumination. . . 104 college students.". . (p. 219) viewed the materials for speed of reading and visibility (using the Luckiesh-Moss Visibility Meter) at 15 inches from a special reading stand which "consisted of a cylinder 8 (inches) in diameter which could be set in any position from the horizontal to the vertical. . . (and a) flat surface . . . set at 45 (degrees) to the table top .". ., (p. 218) the former approximating "the curvature of a page in a large book lying open on a table.". . (p. 218) (and the latter) "to provide optimal conditions for reading flat copy." (p. 219)

Result: The data provided the following results:

1. "The rate of reading curved print was significantly slower than for flat copy. . . (This) seem(ed) to be due largely to reduced visibility of word forms.". . (p. 221) (which also, i.e. visibility or ease of perceiving words, was retarded significantly for the curved print).
2. "The need for constant changes in accommodation in reading the curved text may also be involved in reducing speed of reading the curved text.

"It is suggested that wider inner margins be employed in large books and magazines to avoid the marked curvature of the printed page now present . . . ." (p. 221)

* * *

3349 Tinker-1960

Tinker, Miles A.
Minnesota U., Minneapolis
LEGIBILITY OF MATHEMATICAL TABLES
Journal of Applied Psychology, 44:2
(April 1960) 83-87. 1 ref.

Problem: "(S)tudy the effect of type size, arrangement of numerals in columns, and space

vs. space plus rules between columns on the speed with which the correct numbers can be located." (p. 83)

Procedure: "Four simulated pages of powers and roots were printed all on one sheet of 70-(pound) sulphide paper with a non-shiny surface. The four simulated pages extended in four blocks from left to right with 1-1/4 (inches) of space between pages. The headings of columns on each page were .". . (p. 83) number, square, cube, square root, and cube root. "There were 50 numerals in each column so that the four pages listed . . . powers and roots for the numbers 300 to 499. Numerals in the (number) column were in bold face and the (others) in ordinary printing. (All) numerals were . . . EXCELSIOR . . . (and) were the same height. . . (p. 83) All testing was done individually under 25 (foot-candles) of well diffused illumination. In the nine studies completed there were 24 to 30 (subjects) in each, a total of 246. . . (p. 87) The particular typographical arrangement employed in each substudy .". . (p. 83) was as follows:

1. Six and eight point type were compared. "Numerals in columns were grouped by fives and there was one pica (1/6 inch) of space between columns." (p. 83)
2. For "grouping of numerals in columns for 6-point type(, s)et solid (no grouping), grouping by tens, and grouping by fives were compared." (p. 84)
3. This substudy was the same as "2" above, except that numerals were in 8-point type.
4. "Space vs. space plus rules between columns was compared for 6-point type set solid." (p. 85)
5. This substudy was the same as "4" above, except that numbers were grouped by tens.
6. This substudy was also the same as "4" above, except that numbers were grouped by fives.
7. "Space vs. space plus rules between columns for 8-point type set solid was compared." (p. 85)
8. This substudy was the same as "7" above, except that numbers were grouped by tens.
9. This substudy was also the same as "7" above, except that numbers were grouped by fives.

Result: The studies yielded the following results (which correspond numerically to the individual procedures shown above):

1. "(T)he differences in time were always in favor of the 8-point type, but . . . were not statistically significant . . . ." (p. 83)
2. "Both grouping by tens and by fives were more effective than set solid, and grouping by fives tended to be better than by tens." (p. 84)
3. "In the . . . (cubes and square roots) only the five grouping was significantly better than set solid for square roots. The rest of th(e) differences were not significant." (p. 84)
4. "No significant differences were found." (p. 85)

5. "The results (were) somewhat in conflict in that space appear(ed) best for cubes and rules (one pica plus a rule) best for square roots. The other differences were not significant." (p. 85)
6. "The space alone was significantly better for finding square roots and cube roots. It made no difference with squares." (p. 85)
7. "No significant differences appear(ed)." (p. 85)
8. "Rules between columns were significantly better for squares and square roots. The other differences were not significant." (p. 86)
9. "Rules between columns led to significantly faster responses in finding square roots and cube roots. The other differences were not significant." (p. 86)

In general, these results indicated the following:

1. "When numerals are grouped by fives in columns, 6- and 8-point type were equally effective in promoting location of powers and roots." (p. 87)
2. "Grouping numerals in columns by fives or tens tends to promote quick finding of powers and roots. In general, the grouping by fives tends to be more effective . . . for both 6- and 8-point type." (p. 87)
3. "Apparently it makes little difference whether one pica space or (this) plus a rule between columns is used in tables of powers and roots. In this . . . the results were not entirely unequivocal." (p. 87)

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3320 Tinker-1963

Tinker, Miles A.
LEGIBILITY OF PRINT
Ames, Iowa, Iowa State University Press, 1963,
329p., 238 refs.

Abstract: This comprehensive (too long to delineate here) book is one of a series dealing with research in human communication. It is based primarily on previous experimentation by Tinker and Paterson that is reported on elsewhere. Hence, what follows here is only an outline of its contents.

Outline:

I. Introduction.
  A. General.
  B. Print for adults and children.
  C. Legibility versus readability.
  D. Nature of legibility.
  E. Legibility: methods of investigation.
    1. Speed of perception.
    2. Perceptibility at a distance.
    3. Perceptibility in peripheral vision.
    4. Visibility.

5. The reflex blink technique.
6. Rate of work.
7. Eye movements.
8. Fatigue in reading.

F. Definition of legibility.

II. Methodology and definitions.

A. General.
B. Visibility measurement.
C. Distance method.
D. The short-exposure method.
E. The focal variator method.
F. Rate of involuntary blinking method.
G. Reliability and validity of measurement.
H. Speed-of-reading method.
I. Measurement of eye movements.
J. Length of work period.
K. Measurement cautions.
L. Summary.

III. Legibility of letters and digits.

A. General.
B. Upper-case letters.
C. Lower-case letters.
D. Legibility of digits.
E. Summary.

IV. Kinds of type.

A. General.
B. Printing practice.
C. Styles of type face.
D. Italic print versus roman lower case.
E. Capitals versus lower case.
F. Mixed type forms.
G. Summary.

V. Size of type.

A. General.
B. Printing practice.
C. Subsidiary research on type size.
D. Speed-of-reading studies.

VI. Width of line.
   A. General.
   B. Printing practice.
   C. Experimental results.
   D. Line widths for 10-point type.
   E. Line widths for 12-point type.
   F. Line widths for 8-point type.
   G. Line widths for 6-point type.
   H. Simultaneous variation of type size and line width.
   I. Summary.

VII. Leading and relationship of leading, type size, and line width.
   A. General.
   B. Printing practice.
   C. Experimental study of leading.
   D. Leading with 10-point type.
   E. Leading with 8-point type.
   F. Type size versus leading.
   G. Leading and line width in relation to type size.
   H. Relative legibility of six sizes of type.
   I. Summary.

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   B. Size of full page.
   C. Margins.
   D. Single versus multiple-column printing.
   E. Inter-columnar space and rules.
   F. Paragraphing arrangements.
   G. Vertical versus horizontal printing.
   H. Summary.

IX. Color of print and background.
   A. General.
   B. Black print versus white print.
   C. Legibility in the ordinary reading situation.
   D. Perceptibility of black and white print.
   E. Perceptibility at a distance.
   F. Black print on tinted paper.
   G. Colored print on colored paper.
   H. Speed of reading.
   I. Trends in use of colored print on tinted papers.
   J. Summary.

X. Printing surfaces.
   A. General.
   B. Experimental studies.
   C. Thickness of paper.
   D. Summary.

XI. Cumulative effect of combining nonoptimal typographic arrangements.
   A. General.
   B. Experimental results.
   C. Summary.

XII. Newspaper typography.
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   B. Printing practice.
   C. Legibility of newspaper type faces.
   D. Leading.
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   F. Size of type.
   G. Newspaper headlines.
   H. Reductions in size of newspaper print.
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   E. Handwriting.
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   G. Print in comic books.
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   I. Dictionary printing.
   J. Items in bibliographies.
   K. Telephone directories.
   L. Library of Congress cards.

M. Timetable typography.

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O. Summary.

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C. Intensity of illumination.

D. Recommended practice in lighting.

E. Light intensities adequate for reading.

F. Distribution of illumination.

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B. Light source and the reader.

C. Proper slope for the reading page.

D. Angular alignment and reading ease.

E. Flat versus curved print.

F. Effect of vibration on reading.

G. Length of the reading period.

H. Summary.

Bibliography: 238 annotated citations.

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3265 TinkPat-1941

Tinker, Miles A. and Paterson, Donald G.
Minnesota U., Minneapolis
EYE MOVEMENTS IN READING A MODERN TYPE FACE AND OLD ENGLISH
American Journal of Psychology, 54:1 (January 1941) 113-114.

Problem: "(D)etermin(e) . . . the difference in speed of reading . . . (CLOISTER BLACK) in comparison with . . . (SCOTCH ROMAN) . . . ." (p. 113)

Procedure: "The eye movements of each of 20 college students were photographed while reading 10 paragraphs from the Chapman-Cook Speed of Reading Test, Form A, set in CLOISTER BLACK (Old English) and 10 different paragraphs from Form B of the same test set in SCOTCH ROMAN. Practice effects were equated by systematic variation of test-forms and subjects). . . All paragraphs were printed as follows: Lower case, 10 point, 19 pica line-width, set solid, on egg-shell paper stock." (p. 113) Eye movements measured were fixation frequency, words per fixation, pause duration, perception time, and regression frequency.

Result: "The results . . . show(ed) that the eye-movement patterns are more efficient in

reading SCOTCH ROMAN than in reading CLOISTER BLACK. The detailed findings show that the reading of CLOISTER BLACK resulted in a 5.0 (percent) increase in the number of fixations (significant beyond the 5 percent level of confidence) and a 5.3 (percent) decrease in the number of words per fixation (beyond 5 percent). The average duration of the fixational pauses, however, was only slightly increased (1.3 percent---beyond the 30 percent level). Perception-time was lengthened by 6.4 (percent) (beyond 5 percent) and there was a 10.7 (percent) increase in the number of regressions (between 5 percent and 10 percent). . . It is somewhat surprising to discover that the reading of CLOISTER BLACK, which is read at a strikingly slower rate than SCOTCH ROMAN (about 12 percent in previous performance tests), should not produce an equally striking difference in the analytical eye-movement records. . . It is suggested that the difficulty encountered in reading OLD ENGLISH type is due to the necessity for discriminating details in the perception of word and phrase units." (p. 113-114)

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2726 TinkPat-1942

Tinker, Miles A. and Paterson, Donald G.
Minnesota U., Minneapolis
READER PREFERENCES AND TYPOGRAPHY
Journal of Applied Psychology, 26:1
(February 1942) 38-40

Problem: "(D)etermine the extent to which judged legibility and judged 'pleasingness' agree or disagree with each other." (p. 38)

Procedure: "(P)rinted samples were presented to college students who were instructed 'to arrange them in order from most . . . to least legible.' Legibility was defined as 'ease and speed of reading.' In a similar manner, pleasingness judgments were obtained from a different group of . . . students who were instructed to rank the same samples in order from most . . . to least pleasing. No attempt was made to define 'pleasingness.'. . Each printing sample consisted of five paragraphs from the Chapman-Cook Speed of Reading Test printed in 10 point SCOTCH ROMAN, 19 pica line width, set solid on eggshell paper stock and in the typographical arrangements . . ." of lower case vs. bold face (using 100 subjects), and lower case vs. all capitals (using 320 subjects). "(O)ther typographical arrangements studied were: styles of type face, combinations of colored print and colored paper stock, leading, size of type, line width, paper surface, lower case versus italics, simultaneous variation of line width and type size, space and lines between columns, regularity of alignment versus indentation of alternate lines at left and right ends and simultaneous variation of type size and leading." (p. 38-40)

Result: "(R)eaders believe that lower case is far more legible and . . . pleasing than bold face, although both kinds . . . are actually read at the same rate. . . (L)ower case is read much more rapidly than all capitals and readers rank lower case ahead of all capitals both with respect to legibility and pleasingness." Thus, there is a "striking agreement between judged legibility and pleasingness." The same was true of the other typographical variations, with "only a slight disagreement . . . (h)ere and there . . . In general, the agreement is so close that we are warranted in concluding that judged legibility may be accepted as equivalent to pleasingness." However, "(o)ur data fail to disclose the causal relationship involved." Thus, "(t)he printer should be guided by the facts regarding the speed with which particular typographical arrangements can be read, and also by reader judgments of legibility. (sic) When a printing arrangement is shown to promote rapid reading and readers judge this arrangement to be legible, the printer, presumably would employ it. When two or more printing arrangements are equally legible, the printer presumably would employ the one judged to be most legible. However, when the most

efficient printing arrangement is judged to be less legible than another, then the printer will be forced to decide whether or not he will cater to the opinions of the readers." (p. 38-40)

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3329 TinkPat-1943

Tinker, M. A. and Paterson, D. G.
DIFFERENCES AMONG NEWSPAPER BODY TYPES IN READABILITY
Journalism Quarterly, 20:2 (June 1943) 152-155
Also in READINGS IN EXPERIMENTAL INDUSTRIAL PSYCHOLOGY, Milton L. Blum, Editor, (New York, Prentice-Hall, 1952), p. 282-284

Problem: Establish the relative readability of newspaper type faces.

Procedure: Reading from two Forms of the "Chapman-Cook Speed of Reading Test", nine groups of 100 high school seniors each participated in an experiment that compared nine different newsprint fonts with a standard that was one of the nine.

Result: The three most readable fonts were: OPTICON , REGAL NO. 1 , and "CENTURY EXPANDED". PARAGON , EXCELSIOR , and IDEAL read significantly faster than the standard. IONIC NO. 2 and TEXTYPE , while slightly faster than the standard, IONIC NO. 5 , showed no statistically significant differences. It was only coincidental that the standard was apparently read more slowly than any of the other faces.

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3359 TinkPat-1944a

Tinker, Miles A. and Paterson, Donald G.
Minnesota U., Minneapolis
EYE-MOVEMENTS IN READING BLACK PRINT ON WHITE BACKGROUND AND RED PRINT ON DARK GREEN BACKGROUND
American Journal of Psychology, 57:1 (January 1944) 93-94.

Problem: Determine the effect on eye-movements in the reading of black print on a white ground and red print on a dark green ground.

Procedure: "The eye-movements (fixation frequency, words per fixation, pause duration, perception time, and regression frequency) of each of 20 university students were photographed while reading . . . (t)en paragraphs from the Chapman-Cook Speed of Reading Test, Form A, . . . printed with Ruxton's black ink on white rainbow cover-stock and 10 paragraphs from Form B of the same test . . . printed with Ruxton's Tulip red ink on green rainbow cover-stock. All paragraphs were set SCOTCH-ROMAN lower case, 10-point type, 19-pica line width, set solid." (p. 93)

Result: From the results, "(i)t (was) apparent that the red-on-dark-green text (was) read with only the greatest difficulty. . . They reveal(ed) . . . marked difference(s significant beyond the 1 percent level of confidence) in all eye-movement measures (black/white superior to red/green in the following: fixation frequency = 24.8 percent, words per fixation = 20.2 percent, pause duration = 14.5 percent, perception time = 42.6 percent, and regression frequency = 35.2 percent). . . The retardation (total perception-time of) 42.6 per cent . . . closely approximate(d) the (previously assembled) performance reading-test results (39.5 percent retardation with red/green). . . The difficulty encountered . . . appear(ed) to be due primarily to poor visibility of the printed characters. In other words, the rapid perception of word form and phrase units which occurs in reading ordinary copy is no longer possible under conditions of minimal brightness-contrast . . . ." (p. 94)

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3328 TinkPat-1944b
Tinker, Miles and Paterson, Donald G.
Minnesota U., Minneapolis
WARTIME CHANGES IN NEWSPAPER BODY TYPE
Journalism Quarterly, 21:1 (March 1944) 7-11, 2 refs.

Problem: "What modifications can be made in typography to save paper and at the same time maintain readability . . . ." (p. 7)

Procedure: Several unprinted investigations were carried out using Forms A and B of the Chapman-Cook Speed of Reading Test. "In each comparison of two typographical arrangements, 85 to 100 subjects read Form A as a standard and then Form B in a changed typography. . . In each test form there were thirty sections of thirty words each. A word must be crossed out in each section to show that it has been read with understanding. . . All sections were in IONIC type face on newspaper stock." (p. 8)

Result: "(N)o significant change in readability of newsprint was found for certain comparisons. Thus:

1. "7 point on 8 point slug, 11-1/2 pica line = 8-1/2 point on 9-1/2 point slug, 12 pica line.
2. "7 point on 9 point slug, 12-1/2 pica line = 8 point on 9-1/2 point slug, 12-1/2 pica line.
3. "7 point on 9 point slug, 12 pica line = 8 point on 10 point slug, 12 pica line.
4. "7 point on 8 point slug, 12 pica line = 8 point on 10 point slug, 12 pica line.
5. "8 point on 10 point slug, 12 pica line = 9 point on 11 point slug, 12 pica line.

"The(s)e comparisons indicate that text in 7 . . . on 8 point slug, printed in 11-1/2 to 12-1/2 pica line widths, is read as rapidly as text in a slightly larger type size. . . (H)owever, . . . it would not be safe to reduce . . . below 7 point . . . . A consistent advantage was found when one point leading was employed . . . . But two point leading was no better than one. However, readers . . . prefer(red) two . . . over one point and . . . one . . . over solid. . . One-half to one pica change in line width in the region of 12 picas was found to produce no significant changes in readability. . . It would seem therefore, that 7 point on 8 point slug . . . in a 11-1/2 to 12-1/2 pica line width . . . may be (safely) employed . . . (and) may save considerable paper. . . (A)lso . . . paper may be saved by reducing margins . . . (which) do not (themselves) promote greater readability. . . It was also found that text was read just as fast when a rule without space was employed as when greater intercolumnar space was present." (p. 7-8)

Problem (collateral): Conduct a survey of newspaper printing practice.

Procedure (collateral): The first survey was conducted in 1935 and had a response of 89 replies to questionnaires. The follow-up survey in 1942 received 87 replies. In each case, the "information requested . . . was: 'The front page news columns of your paper are printed usually as follows: A. Style of type face and name of type founder or manufacturer. B. Size of type in points. C. Width of line of print in picas. D. Space between lines (leading).' The same information was requested for the editorial page." (p. 8)

Result (collateral): "The data were assembled in (the following) tables . . . (:)

| designs of type | times used on front page 1935 | 1942 | times used on editorial page 1935 | 1942 |
|---|---|---|---|---|
| IONIC | 30 | 22 | 20 | 16 |
| IDEAL | 28 | 21 | 22 | 17 |
| EXCELSIOR | 14 | 17 | 13 | 12 |
| REGAL | 5 | 13 | 4 | 10 |
| CENTURY | 2 | 1 | 7 | 10 |
| OLD STYLE | 2 | 0 | 3 | 1 |
| TEXTYPE | 2 | 0 | 1 | 0 |
| NO. 2 | 2 | 0 | 0 | 0 |
| ROMAN | 1 | 0 | 4 | 1 |
| CLASSIC | 1 | 0 | 2 | 1 |
| MODERN | 1 | 0 | 1 | 0 |
| CHELTENHAM | 1 | 0 | 2 | 0 |
| ANTIQUE | 0 | 0 | 5 | 3 |
| DE VINNE | 0 | 0 | 4 | 2 |
| BODONI | 0 | 0 | 1 | 0 |
| OPTICON | 0 | 5 | 0 | 6 |
| PARAGON | 0 | 2 | 0 | 1 |
| CORONA | 0 | 2 | 0 | 2 |
| LINOTYPE 2 | 0 | 1 | 0 | 1 |
| MERGANTHALER 2 | 0 | 2 | 0 | 1 |
| INTERTYPE 655 | 0 | 1 | 0 | 1 |
| BODONI (sic) | 0 | 0 | 0 | 1 |
| SPARTAN | 0 | 0 | 0 | 1 |

| size of type | front page 1935 | 1942 | editorial page 1935 | 1942 |
|---|---|---|---|---|
| 12 | 0 | 0 | 4 | 2 |
| 10 | 0 | 0 | 23 | 29 |
| 9-1/2 | 0 | 0 | 0 | 1 |
| 9 | 0 | 0 | 10 | 12 |
| 8-1/2 | 1 | 2 | 0 | 3 |
| 8 | 17 | 30 | 32 | 28 |
| 7-3/4 | 0 | 1 | 0 | 0 |
| 7-1/2 | 16 | 20 | 3 | 3 |
| 7 | 45 | 31 | 16 | 9 |
| 6-3/4 | 6 | 3 | 1 | 0 |
| 6-1/2 | 4 | 0 | 0 | 0 |

| width of line | front page 1935 | 1942 | editorial page 1935 | 1942 |
|---|---|---|---|---|
| ? | 0 | 0 | 1 | 0 |
| 25-1/2 | 0 | 0 | 2 | 1 |
| 24-1/2 | 0 | 0 | 9 | 5 |
| 24 | 1 | 0 | 3 | 5 |
| 23-1/2 | 0 | 0 | 1 | 0 |
| 23 | 0 | 0 | 1 | 1 |
| 21 | 0 | 0 | 1 | 0 |
| 19 | 0 | 0 | 1 | 0 |
| 18-1/2 | 0 | 0 | 1 | 0 |
| 18 | 0 | 0 | 17 | 16 |
| 17-1/2 | 0 | 0 | 2 | 4 |
| 17 | 0 | 0 | 2 | 0 |
| 16-1/2 | 1 | 1 | 2 | 3 |
| 16 | 0 | 0 | 20 | 14 |
| 15-1/2 | 0 | 0 | 2 | 8 |

| width of line | front page 1935 | front page 1942 | editorial page 1935 | editorial page 1942 |
|---|---|---|---|---|
| 15 | 0 | 0 | 5 | 14 |
| 14-1/2 | 0 | 0 | 1 | 1 |
| 14 | 0 | 0 | 1 | 2 |
| 13-1/2 | 1 | 0 | 4 | 5 |
| 12-1/2 | 9 | 6 | 1 | 1 |
| 12 | 77 | 80 | 12 | 7 |
| **leading** | **front page 1935** | **front page 1942** | **editorial page 1935** | **editorial page 1942** |
| 4 | 0 | 0 | 2 | 2 |
| 3 | 0 | 0 | 7 | 6 |
| 2-1/2 | 2 | 1 | 2 | 4 |
| 2-1/4 | 1 | 0 | 0 | 1 |
| 2 | 11 | 9 | 44 | 43 |
| 1-3/4 | 0 | 1 | 0 | 0 |
| 1-1/2 | 3 | 2 | 1 | 1 |
| 1-1/4 | 4 | 2 | 1 | 0 |
| 1 | 33 | 36 | 23 | 18 |
| 3/4 | 1 | 2 | 0 | 0 |
| 1/2 | 19 | 18 | 0 | 0 |
| 1/4 | 1 | 2 | 0 | 0 |
| 0 | 14 | 14 | 9 | 12 |

(above from p. 8 & 9)

* * *

2570 TinkPat-1946a

Tinker, Miles A. and Paterson, Donald G.
Minnesota U., Minneapolis
EFFECT OF LINE WIDTH AND LEADING ON READABILITY
OF NEWSPAPER TYPE
Journalism Quarterly, 23:3 (September 1946) 307-309

Problem: "(D)etermine the effect of varying line width and leading upon the readability of newspaper body type." (p. 309)

Procedure: For 8-point EXCELSIOR type on newsprint, compare the readability of a standard (12-pica line width with 2-point leading) with variations set 6-, 12-, 18-, 24-, 30-, and 36-pica line widths, each line width being set solid and with 1/2-, 1-, and 2-point leading. A total of 2016 high school senior subjects read the materials in Forms A and B of the Chapman-Cook Speed of Reading Test.

Result: "In general, the data indicate . . . (the following):

1. "An 18-pica line width with 1 or 2 point leading produces most readable text.
2. "Textual materials with a rather wide range of line widths and leading are equally legible.
3. "Very short and relatively long line widths produce poor readability except when the long lines are generously leaded. . .

"In general, judgments of pleasingness tended to agree with judgments of relative legibility . . . For 6 and 24 pica line widths, however, 1-point leading was considered more pleasing than 2 points . . . ." (p. 309)

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2728 TinkPat-1946b

Tinker, Miles A. and Paterson, Donald G.
Minnesota U., Minneapolis

READABILITY OF MIXED TYPE FORMS

Journal of Applied Psychology, 30:6
(December 1946) 631-637

Problem: "(M)easure the readability of and reader preferences for two medley (or mixed, and sometimes called 'change of pace') typographical arrangements in comparison with straight-forward lower case Roman type." (p. 631)

Procedure: "Three groups of 94 college students each served as subjects. . . in the classroom situation . . . Reading material consisted of Forms A and B of the Chapman-Cook Speed of Reading Test. . . There were 30 paragraphs of 30 words each in each test form. Reading time allowed was 1-3/4 minutes on each form. . . In each group (of subjects), Form A was the standard. Each subject read the standard . . . first, followed by Form B . . . . The order of presenting the test forms was systematically varied. . . (T)est forms were printed (on newsprint paper stock) in the following typographical arrangements:" (p. 631 & 633)

| type face | style | stroke-width | case | size (points) | line-width (picas) | leading (points) | other |
|---|---|---|---|---|---|---|---|
| (control - Form A) | | | | | | | |
| EXCELSIOR | Roman | regular | lower | 7 | 12 | 1 | - - - |
| (uniform - Form B) | | | | | | | |
| EXCELSIOR | Roman | regular | lower | 7 | 12 | 1 | - - - |
| (medley no. 1 - Form B) | | | | | | | |
| EXCELSIOR | Roman | regular | lower | 10 | 12 | 2 | - - - |
| EXCELSIOR | italic | regular | lower | 10 | 12 | 2 | - - - |
| EXCELSIOR | Roman | regular | lower | 7 | 12 | 1 | - - - |
| MEMPHIS | Roman | bold | lower | 7 | 12 | 1 | - - - |
| MEMPHIS | Roman | bold | lower | 7 | 10-1/2 | 1 | - - - |
| EXCELSIOR | Roman | regular | capital | 7 | 12 | 1 | - - - |
| EXCELSIOR | Roman | regular | capital | 7 | 10-1/2 | 1 | - - - |
| MEMPHIS | Roman | bold | capital | 7 | 12 | 1 | - - - |
| EXCELSIOR | Roman | regular | lower | 7 | 11 | 1 | boxed |
| (medley no. 2 - Form B) | | | | | | | |
| EXCELSIOR | Roman | regular | lower | 10 | 12 | 2 | - - - |
| EXCELSIOR | Roman | regular | lower | 7 | 12 | 1 | - - - |
| MEMPHIS | Roman | bold | lower | 7 | 12 | 1 | - - - |
| EXCELSIOR | Roman | regular | capital | 7 | 12 | 1 | - - - |
| MEMPHIS | Roman | bold | capital | 7 | 12 | 1 | - - - |
| MEMPHIS | Roman | bold | lower | 10 | 9 | 2 | - - - |
| MEMPHIS | Roman | bold | lower | 10 | 10-1/2 | 2 | - - - |
| MEMPHIS | italic | bold | lower | 10 | 9 | 2 | - - - |
| EXCELSIOR | italic | regular | capital | 10 | 9 | 2 | - - - |
| MEMPHIS | Roman | bold | lower | 10 | 10 | 2 | boxed |
| EXCELSIOR | italic | regular | lower | 10 | 10 | 2 | boxed |

(above from p. 631-633)

"Each variation (in medley No. 1) involved a phrase, a sentence, or one or two paragraphs with repetitions. In medley arrangement No. 2 there was greater variation in line widths and more frequent changes from one arrangement to another within a paragraph, and boxed in paragraphs were used. . . Readability was measured in terms of speed of reading and preferences were determined in terms of judged legibility and judged pleasingness. . . Analysis of the data will reveal the influence upon readability of the medley arrangements in comparison with the standard arrangement." (p. 631 & 633)

Result: "Medley arrangement No. 1 was read 8.35 and medley arrangement No. 2 was read 11.39 per cent more slowly than the 7 point EXCELSIOR in uniform arrangement. This amount of retardation is serious and is seldom shown in non-optimal typography. . . The slower rate of reading the medley arrangements is apparently due to several factors: (a) the slower rate for reading text in all-capitals, in italics and in non-optimal line widths, and (b) the possible distraction produced by frequently shifting from one typographical arrangement to another. . . Judged legibility was in line with readability measurements. The 7 point newsprint in uniform arrangement was judged most legible, medley arrangement No. 1 was next, and medley arrangement No. 2 was rated least legible. . . Medley arrangement No. 1 was rated most pleasing, the uniform 7 point text was next and medley arrangement No. 2 was a poor third. The difference in average rank between the first two, however, was not large. Apparently these readers tended to consider some variation in typography as more pleasing even though they judged such variation to be less legible than uniform typography. . . In deciding to employ a medley arrangement in newspaper printing, the editor should consider whether certain alleged advantages more than compensate for the severe loss in readability and the adverse opinions of readers." (p. 637)

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3362 TinkPat-1949

Tinker, Miles A. and Paterson, Donald G.
Minnesota U., Minneapolis
SPEED OF READING NINE POINT TYPE IN RELATION TO LINE WIDTH AND LEADING
Journal of Applied Psychology, 33:1 (February 1949) 81-82, 1 ref.

Problem: "(D)etermine the influence of line width and leading on the speed of reading 9 point type." (p. 82)

Procedure: "Reading speeds for 8, 14, 18, 30, and 40 pica line widths each set solid and leaded 1 . . ., 2 . . . and 4 points are compared . . . with reading speed for SCOTCH ROMAN printed in 18 pica line width leaded 2 points as a standard. . . (R)eaders (were) 2000 university sophomores." (p. 82)

Result: "The results indicate that optimal rate of reading occurs with line widths of 14 to 30 picas and with 1 to 4 points leading. This may be considered the zone of safety. . . A conservative range would be 16 to 24 pica line width with 1 or 2 points leading when 9 point (SCOTCH ROMAN?) type is used. . . (R)eader preferences show(ed) that readers dislike(d) long . . . and very short lines." (p. 82)

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3262 TinkPat-1950

Tinker, Miles A. and Paterson, Donald G.
Minnesota U., Minneapolis
TYPOGRAPHY AND LEGIBILITY IN READING
Section 9, Chapter II in HANDBOOK OF APPLIED PSYCHOLOGY, Vol. 1, Douglas H. Fryer and Edwin R. Henry, Editors, (New York, Rinehart & Co., 1950), p. 55-60, 7 refs.

Problem: Discuss the process of reading in terms of the problems generated by typography and the reading environment.

Procedure: This review paper discusses reading in the following sections:

I. Introduction.
II. Analysis of the reading act.
III. Typography and legibility.
IV. Legibility.
V. Visibility.
VI. A typical problem.
VII. Recommended typography (including style of type face; type form (italics, bold face, all-capitals, etc.); size of type; width of line; interlinear spacing; type size, line width, and leading; margins; columnar arrangement; space between columns; color of print and background; and paper surface).
VIII. General conclusion.

Result: The following definitions and situations, stated in the first six sections, are given:

1. (introduction) "(O)ptimal typographical conditions promot(e) ease and comfort in reading . . . ."
2. (analysis of the reading act) "(A)pproaches are two: perception and eye-movement studies, and measurements of intelligence and reading achievement." Factors involved, experimental methodology, and difficulties with them are discussed. As, for example, "(t)he importance of intelligence as a determinant of reading proficiency is revealed by the . . . correlation. . . co-efficien(t) range between 0.50 and 0.70."
3. (typography and legibility) "Here one is concerned with suitable illumination and optimal typographical arrangements. . . In what follows the terms legibility and readability are synonymous. Likewise, the terms perceptibility and visibility are synonyms (underlining not by Tinker and Paterson). . . (R)eading printed matter at the ordinary or usual distance of approximately 14 inches. . . deal(s) with the legibility . . . in newspapers, magazines, books, pamphlets, circulars, etc. . . (R)eading printed matter at a distance. . . one is concerned with . . . newspaper headlines, billboards, car cards, window display signs, road signs, labels on packaged goods, etc. . . The distinction is more than verbal . . . ."
4. (legibility) "Complications arise because one printing arrangement may be read more rapidly than another and yet involve eyestrain and visual fatigue to such an extent as to make its use inadvisable. Suitable speed of reading tests are available but suitable fatigue tests are not." Compromise arrangements are discussed.
5. (visibility) "Visibility, or perceptibility of print, refers to the reading of print at the threshold for visual discrimination of words. . . (T)here is evidence that although arrangement A may be better than B in terms of visibility or perceptibility, yet B may actually be read more rapidly than A under ordinary conditions. . . The problem of typography is complicated both by the fact that legibility and visibility are somewhat independent, and by the large number of typographical factors involved in printing." The authors discuss the Luckiesh-Moss Visibility Meter, the

distance and illumination threshold methods, and the tachistoscopic exposure in terms of their experimental utility in varying situations.

6. (a typical problem) "(T)he relative legibility and perceptibility of printing in all-capitals and in lower case (with proper capitalization) . . . is . . . of direct interest to those who write printing specifications for headlines . . . (,) posters, billboard(s) . . ., circulars, . . . names and titles on books, packages, and calling cards. . . In . . . a reliable speed of reading test. . . all-capitals retarded speed of reading by about 12 per cent. . . (M)ovements of the eye . . . show . . . a marked increase in the number of fixations . . . required . . . . This . . . (is) due in part to the fact that the all-capital text requires a 35 per cent increase in . . . printing surface. In addition, 'word form' cues are lacking." Also, subjective judgments of legibility showed 90 per cent of subjects in favor of lower case. In another group of subjects, 94 per cent "voted in favor of lower-case printing." However, "(i)f one were concerned with sheer perceptibility then he would advocate the use of all-capitals . . . (since they) can be recognized at a (39 per cent) greater distance than the same words printed in lower case. . . Unfortunately, such situations are (usually) the very ones which require emphasis on speed as well as on perceptibility. . . (f)or example, billboard advertising and newspaper headlines . . . The visibility of lower case type can . . . be increased by specifying . . . bold face type. . . (A) use for all-capital printing. . . can be justified as a mechanical device for attracting attention. . . (f)or example, . . . want-ads . . . This increased attention value, of course, arises from novelty and contrast."

Typographic recommendations given in section seven are as follows:

1. (type face) "(C)ommonly used . . . or ultramodern type face(s) . . . are equally legible. Readers . . . prefer a . . . face which borders on the bold . . . . TYPEWRITER type (except for novelty) and OLD ENGLISH (except for brief formal messages) should be avoided . . . because of poor legibility."

2a. (type form - italics) "Italics are read more slowly . . . (and r)eaders overwhelmingly choose Roman as being more legible as well as more pleasing. . . <u>(I)talics should be employed sparingly and then only when added emphasis is desired.</u>"

2b. (type form - bold face) "Bold face . . . is read just as rapidly . . . . Readers believe, however, that (it) is less legible and less pleasing. . . **(It) should be used only when emphasis is desired or when perceptibility at a distance is involved.**"

2c. (type form - capitals) "All-capital printing is read much more slowly . . . . READERS JUDGE ALL-CAPITALS TO BE QUITE ILLEGIBLE AND TO BE FAR LESS PLEASING THAN LOWER CASE. . . (I)t may be used as a device to attract attention."

3. (type size) "Small sizes (6 and 7 point) and unusually large . . . sizes (14 point or larger) are less legible . . . . The intermediate . . . sizes (9, 10, 11 and 12 point), when appropriate space between lines and suitable line widths are used, are all equally legible . . . Of these . . ., 11 point is liked slightly more . . . . Larger . . . sizes should be used . . . where emphasis is desired or where perceptibility . . . is involved."

4. (line width) "(S)hort . . . (less than 2-1/3 inches) and . . . long . . . widths (more than 4-2/3 inches) are difficult to read . . . Readers . . . believe (moderate widths) to be more legible and more pleasing. In general, . . . 3 inches (is) recommended."

5. (line spacing) "Leading (2 points) improves the legibility of all type sizes except 12 point and larger. Readers . . . prefer 2-point . . . (for) legibility as well as . . . aesthetics. In general leading is . . . more important than line width."

6. (type size vs. line width vs. line spacing) These "factors . . . are intimately interrelated . . . (A) series of tables showing safety zones is presented in the Paterson-Tinker book (1940)."

7. (margins) "Most . . . printing devotes far more space . . . than is necessary. . .

(M)argins do not promote fast reading."

8. (columnar arrangement) "Double-column printing is preferred by readers . . . (, ) would introduce . . . economies . . . (, and) would promote legible printing by preventing the frequent use of excessively long lines of print. . . (H)owever, . . . (it) should (not) lead to the use of excessively short lines."
9. (columnar spacing) "(A)n intercolumnar rule or line does not promote legibility in comparison with the use of a one-half pica space (about 3/32 inch)."

10a. (contrast) "(B)lack print on a white background is much more legible than white on black. . . The occasional use of white on black . . . can be justified . . . an an attention-getting device."

10b. (color) "Colored print on colored backgrounds is less legible than black on white. If used, . . . a dark-colored print should be used on a light-colored background."

11. (paper surface) "Printing on highly glazed . . . stock is . . . as legible as . . . on dull . . . stock. Nevertheless, because of . . . unsatisfactory . . . illumination, one should employ . . . dull finish, opaque paper stock."

"Studies concerned with the legibility of type point to an amazing adaptability of the human eye in adjusting to . . . typographical arrangements. . . This does not mean . . . that one . . . arrangement is read just as easily and as rapidly as any other. . . (I)mprovement in legibility can be made by seeking optimal printing arrangements." (quoted material in the preceding was taken from p. 55-59)

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3357 Uhlaner-1941

Uhlaner, Julius E.
Iowa State Coll., Ames

THE EFFECT OF THICKNESS OF STROKE ON THE LEGIBILITY OF LETTERS

Proceedings Iowa Academy of Science, Vol. 48, 1941, p. 319-324, 4 refs.

Problem: As "part of a study dealing with the optimal characteristics . . . of highway signs. . . deal with the isolation of the stroke (thickness) as a factor in legibility." (p. 319)

Procedure: Experiment I - Sixteen subjects, in a total of 1344 observations, viewed four, dull black on mat white, 3-inch block (height = width) letters (E, N, C, and P---corrected to 100 percent Clason and Snellen visual acuity) outdoors (in shade) under a daylight illumination level of 250 to 550 foot-candles. Stroke-width of the letters was varied between 8 percent and 32 percent of the height at 4 percent intervals. Each subject made three observations for each letter/stroke-width combination. Two observations were made with the subject approaching the stimulus from 350 feet, and the third with the subject withdrawing from the stimulus, in each case until the legibility distance was reached. "A block letter using an eight per cent stroke is equal to a .4 minute angle of the separate members of the letter and a 20 per cent stroke to a one minute angle. . . The Snellen criterion of 20/20 vision is a five minute angle for the . . . letter and a one minute angle for its individual members as seen from the standard distance." (p. 319) Experiment II - This experiment was identical to Experiment I with the following exceptions: Four additional letters (F, Z, B, and O) were used. Stroke-widths used were 16, 18, and 20 percent of the height. Fifteen subjects participated in a total of 1080 observations.

Result: The following conclusions were stated:

1. "(O)ptimal stroke . . . is . . . closest to 18 per cent of the . . . height . . .
2. "The general acceptance of constancy of angle should make this applicable to any size block letter. . .
3. "The legibility distances obtained for letters having a stroke of 16 and 20 per cent are fairly close . . .
4. "A 16 per cent stroke, on the average, gives a higher legibility distance than a 24 per cent stroke." (p. 323)

"(D)ata are presented with a full knowledge of the limits of application to letters of other characteristics. . . (S)uggest the need for reduction in the width of stroke with the reduction of the height-width ratio to assure maximum legibility." (p. 324)

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3280 Ullman-1958
Ullman, William
TEST-TUBE HIGHWAY AIDS SIGN RESEARCH
Automotive News, 32:3268 (November 11, 1957) 16
Abstract in Highway Research Abstracts, 28:4
(April 1958) 17-18

Abstract: "Two of the most important cities in the Washington area during the past month have been Metropolis and Utopia, each with a population of zero in the last census. They have no existence except on some of the biggest highway signs you ever saw, but the ability of motorists to read and understand them will determine the types of sign to be used throughout the new 41,000-mile Interstate System.

"The test area for the Bureau of Public Roads is a winding, three-mile loop of unopened highway in nearby Maryland. Spotted along the sides of the road---and over it---are several dozen signs of varying color and design. They are alternately covered or uncovered, according to the test plan.

"All day and through half the night for the past 30 days, volunteer motorists of all ages have been spinning through a 48-mile run through the test course, reporting what they see to highway engineers seated beside them. Small roadside markers bearing Greek letters tell engineers precisely at what distance drivers can read each portion of the signs.

"But the best background color for both day and night driving hasn't been selected yet, though the 15,000 separate pieces of information collected in the Maryland test should provide the right answers. Test colors are black, blue, red and green, some of them luminous.

"The information obtained will be of use to states, counties and foreign countries as well as to Federal road planners." (p. 17-18)

* * *

1798 Utman-1963
Utman, R. E.
Business Equipment Manufacturers Assn., New York
STANDARDS FOR INFORMATION PROCESSING: A PROGRESS REPORT
Computers and Automation, 12:7 (July 1963) 9-12

Problem: Report on current activity in the development of standards for information processing, including character and symbol sets used in mechanized information processing equipment.

Procedure: The following are some of the organizations that have been formally interested in standardization in information processing since 1960:

- American Standards Association (ASA); X3, X4, and X6
- International Organization for Standardization (ISO); TC 95 and TC 97
- Business Equipment Manufacturers Association (BEMA); sponsor of X3, X4, and TC 97
- International Electro-Technical Commission (IEC); TC 53
- Electronic Industries Association (EIA); sponsor of X6

Committees X3 and TC 97 are particularly concerned with the standardization of character and symbol sets and codes. Of seven working subcommittees in X3, the first, X3. 1, is concerned with optical character recognition and includes task-groups on font development, printing, and applications. A closely related subcommittee, X3. 7, which is concerned with magnetic ink character recognition, has "assumed the work of the Office Equipment Manufacturers Committee in conjunction with the American Bankers Association . . . ." (p. 9) A manufacturer's patent application is presently holding this work in abeyance. Further, "the French proposal CMC-7, based on BULL equipment, has recently been adopted by the EBA (European Bankers Association) as a European Common Market standard . . . ." (p. 10) In general, "the European Computer Manufacturers Association (ECMA) TC-4 and the European Bankers Association (EBA) are carrying out similar work in parallel to X3. 1 and X3. 7. It is hoped that ISO/TC 97/SC 3---Character Recognition---will compare the X3. 1 work with the ECMA TC-4 work on a numeric and subsequent alphanumeric font . . . ." (p. 9) Subcommittee X3. 2, on character sets and data formats, has investigated the following: "Set Size: Need for letters; digits; programming language characters of COBOL and ALGOL; data processing characters like @, $, %; transmission characters like null/idle, delete/idle, 'Who are you', start of message; carriage control characters like bell, carriage return, horizontal tab . . . . Collation Sequence: . . . where possible the upper case---lower case arrangement of characters on a typewriter should correspond to a single bit difference between characters of such a pair . . . . International Considerations: Provision was made for expansion of the alphabet." (p. 10) Subcommittee "X3. 6 on Problem Description and Analysis has devoted the last two and a half years . . . to the development of a proposed American standard flow chart symbolism for information processing . . . . Internationally, . . . a counterpart ISO/TC 97/WG G . . . group was approved (to) . . . consider . . . Flow Chart Symbol draft proposals from the Netherlands, IFIP (International Federation of Information Processing Societies), ECMA and the USA." (p. 12)

Result: Proposed American Standards and International Draft Recommendations are shown in the paper in a report of progress. It was deemed pertinent to this volume to include information concerning work in this area in order to show the directions that are being taken in the development of character faces for machine reading that are also humanly recognizable.

* * *

2249 Vernon-1931

Vernon, Magdalen D.
THE EXPERIMENTAL STUDY OF READING
London, Cambridge University Press, 1931, 190 p.

Problem: "The purpose of this book is to give a concise account of . . . experimental work . . . which throws . . . light upon the psychology of reading." (p. xiii)

Procedure: The work is a review of ocular physiology, psycho-ocular reaction, experimental method (for reading tests and eye movement), and the result of previous experimental work in readability and legibility (the author's and others'). Hence, the points pertinent here are found below (*) interspersed in an outline of contents.

Result:

I. Methods of observing and recording eye movements.
   A. Direct observation.
   B. Devices attached to the eye.
   C. Photographic recording.
   D. Miscellaneous methods.

II. Types of eye movement.
   A. Simple reactive and sweeping eye movements.
   B. Convergent and divergent movements.
   C. Torsional movements.
   D. Pursuit movements, co-ordinate compensatory movements and reactive compensatory movements.
   E. Fixation pauses.

III. Sensations of eye movement.
   A. Kinaesthetic sensations of reflex eye movement.
   B. Spatial perception.
   C. Perception of depth and distance.
   D. Perception of the rate of movement.

IV. Eye movements in reading.
   A. General description.
      *. "The location and relative duration of the fixation pauses in the printed line are in part functions of fixed habits of movement, and tend to remain the same whatever the words in the line; but they are also affected by the nature of the reading material." (p. 45)
      *. "Dearborn found that the exact points fixated might be in any part of the words, or even in the spaces between them." (p. 46)
      *. "(W)ith readers . . . whose maturity in reading varied greatly, there is no correlation between length and duration (of fixations) . . . ." (p. 48)
   B. Variation of eye movements with objective factors in reading.
      *. "(T)here is an increase in the number of fixation pauses in . . . longer printed lines, but this . . . is not appreciable unless the difference . . . is about 4 cm. . . In any case, it does not appear that there is any increase in the number of fixations relative to the number of words in the line." (p. 49-50)
   C. Variation of eye movements with age and maturity of reader.
   D. Differences of eye movements in silent and oral reading.

E. Variation of eye movements with the purpose of the reading.
 *. "(R)apid reading is different from scanning (and skimming), careful reading and detailed studying, summarizing, paraphrasing, analysing for style, etc., and proof-reading." (p. 58)

F. Variation of eye movements with the nature of the reading material.
 1. The native language.
 2. Disconnected words.
 3. Foreign languages.
 4. Spelling.
 5. Mathematics.

G. Variation of eye movements with motor habits.

V. Visual perception in reading.

A. Visual perceptual processes.

B. The nature of the perceptual processes in reading.
 *. "It seems improbable that we perceive individually every letter of every word. . . Cattell found that . . . the average reader could perceive three to four single letters or digits, two disconnected words containing up to twelve letters, or a sentence of four words. . . Indeed, Cattell found that it took longer to name single letters than single words . . . ." (p. 111-112)
 *. "Erdmann and Dodge . . . found that a whole word could be read even when its individual letters were too far away or too small to be perceived separately and individually. . . (L)ong words, particularly of . . . characteristic form, were more readily recognized than shorter ones." (p. 112) However, "Kutzner . . . found that . . . short words could be recognized at a greater distance . . . . Korte has shown that short words can be more readily recognized in peripheral vision." (p. 112)
 *. "Goldscheider and Müller concluded . . . that words are recognized principally by means of certain 'determining letters', of which the initial letter, letters projecting above or below the line, and vowels, were the most important." (p. 112)
 *. "Messmer considered that the total word form is determined . . . by its length . . . vertical profile . . . relative number of vertical letters (e.g. i, n, m, t, l, etc.) and curved letters (e.g. o, e, c, s, etc.)." (p. 114) However, "(i)f the word is composed principally of one of these types of letters, it will be less readily perceived than if it contains a mixture . . . or several vertical-curved letters (b, d, p, q)." (p. 114)
 *. "Kutzner considered that the important factor in perception (is) the 'form quality' (Gestalt-qualität) . . . determined by length (of word), (and) more particularly by the number of ascending and descending letters . . . their position relative to one another and to the rest of the word." (p. 115) By contrast, "Korte . . . concluded that the 'total optical form' (is) not very important in ordinary reading." (p. 115) Yet, "(h)e agreed with Messmer that words were more easily recognized if they contained . . . long and short letters (with) ascending letters yield(ing) better cues than descending ones." (p. 116)

- *. There is "a tendency (in reading) to preserve the upper contour line of the word, but not the lower. This agrees with . . . Huey, who found that a passage in which the lower halves of the words had been deleted was read much more easily than (one) in which the upper halves . . . had been deleted." (p. 116-117)

C. The perceptual span.

- *. At the "normal reading distance . . . about four letter spaces of normal sized print can be seen foveally, although nearly forty can be seen in macular vision." (p. 122)

D. Variations in the nature of the perceptual processes in reading.

VI. The visual perception and reading of children.

A. The visual perception of children.

B. Children's reading.

- *. "N. B. Smith found that . . . there was much liability to confusion between letters of similar form, such as 'b' and 'd', 'p' and 'q'." (p. 145)
- *. "Wiley stated that a large proportion of errors in children's reading was due to similarity of configuration . . . of letters rather than . . . of the total word form." (p. 147)
- *. "Meek found . . . confusion . . . caused by words with the two final letters the same and less confusion by those with the first two letters the same." (p. 147-148) Also, she concluded that "i", "g", "ll", "o", and "k" seemed to be favorite "'cues' for word recognition. . . The only general conclusion was that the initial and final letters were recognized and remembered better than the middle letters of the words." (p. 148-150)

C. Reading disabilities.

- *. "Orton has attributed reading disability to a purely functional defect of the brain. . . based upon the following (commonly observed) features . . .: (1) confusion of . . . 'p' and 'q', 'b' and 'd', . . . 'was' and 'saw', 'not' and 'ton'; also a tendency to reversal of pairs of letters or of syllables in words; (2) capacity to read and write mirror writing. . . On the other hand, Smith found that (these confusions) (were) frequent with normal readers when letters were presented singly, but was much less marked when . . . combined . . . (in) nonsense syllables." (p. 157-159)

VII. Typographical factors.

A. Investigation of the influence of typographical factors upon reading.

- *. "Pyke found . . . no correlation between the relative legibility of . . . type faces as determined by the tachistoscopic reading of nonsense words, and of prose." (p. 162)
- *. "Hovde has shown that . . . reading rate and legibility . . . is far more affected by differences in the context than by differences in the sensory content; for instance, in the size of type and leading." (sic) (p. 162)
- *. Pyke suggests that "the best ultimate measure (of legibility) would be the degree of fatigue produced by prolonged reading." (p. 162) But he further states that "we have no definite accurate and extrinsic measure of fatigue . . . ." (p. 163)

*. "It is quite possible that the power of accommodation would be more liable to fatigue than any other part of the visual apparatus . . . Unfortunately no satisfactory method of measuring the power of accommodation has been devised." (p. 163)

*. "(F)requently employed criteria of legibility are speed of reading, accuracy of reading, and eye movements." (p. 163)

*. "(O)nly very extreme typographical changes, such as the use of type more than 36 point or less than 6 point . . . or . . . a GOTHIC type face (or HANDWRITING), affected the eye movements appreciably." (p. 164)

B. General typographical standards.

*. "Huey has summarized the findings of the earlier writers with regard to the size of type. . .:

"Height of short letters: 1.5 to 2.0 mm. (about 10 point).
"Width of letters: 6 or 7 per cm.
"Thickness of vertical strokes: 0.25 to 0.30 mm.
"Spaces within letters (between vertical strokes): 0.3 to 0.5 mm.
"Spaces between letters: 0.50 to 0.75 mm.
"Spaces between words: 2.0 mm." (p. 165)

*. "Hovde found that a narrow variation of type size, from 6-3/4 to 8 point, had no significant effect upon the rate of reading." (p. 166)

*. "Paterson and Tinker . . . found that 10 point type was read faster than 6, 8, 12, or 14 point type . . . ." (p. 166)

*. "Blackhurst found that the optimum sizes for children in the first, second, and third and fourth grades . . . were 24 point, 18 to 24 point, and 18 point respectively." (p. 166)

*. "It is possible that a rather small type, even if it produces rapid reading initially, may be more fatiguing eventually." (p. 166)

*. "With regard to the length of line, there seems to be a consensus of opinion that it should not exceed 10 cm. . . (and) should be not less than 7.5 cm. . . ." (p. 166-167)

*. "Javal and Huey state that interlineage should not be used at the expense of body size . . . But (others) seem to show that leading is an advantage with small type. . . Opinion on the whole is favorable to the use of leading with larger sizes of type. . . Bentley . . . found that speed seemed to depend upon the ratio---letter height/interlinear space; thus the optimum interlineage was:

"Approximately 1-1/10 in. for 12 point type,
Approximately 1-1/14 in. for 9 point type,
Approximately 1-1/17 in. for 6 point type."
(p. 167-168)

In general, "(a) printed page always appears clearer and more legible with a moderate amount of interlineage. For normal reading, however, it is probable that an adequate size of type is more important.

*. "(I)t has been suggested that a slight indentation at the left-hand end of alternate lines would not interfere with regular habits, and would help to prevent a return to the line above or the line below the correct one." (p. 168)

- *. "(I)t should be a rule that every book should be printed and bound in such a way that all the printed part of the page lies flat . . . ." (p. 170)
- *. "A compromise (between white and yellow) of cream colour (paper) has been suggested, but the general consensus . . . is in favour of white. The surface should, however, be matt, not glossy, to give diffuse and avoid specular reflection. The paper should . . . be thick enough to prevent the ink from showing through . . . Griffing and Franz found that white, greyish, yellow and red paper were best in order of legibility. . . Hall and Ames . . . found that matt white, medium glossy pink and blue, and glossy white, in order, gave the best legibility. Black ink is . . . considered . . . best." (p. 170)

C. Forms of letters.

- *. In light of suggestions "to alter the form of some of the individual letters . . . one can see that 'o' and 'e', 'a' and 's', 'r', 'n' and 'u', 'f' and 't', 'i' and 'l', 'b', 'h' and 'd' are only slightly differentiated from each other. . . In the writer's work . . . the most common form of definite letter-for-letter substitution which caused a mis-reading was a confusion of the ascending letters, particularly of 'f' and 't', and 'l' and 't'. Confusion of vowels was also frequent, not only of 'o' and 'e', but also of 'a' and 'e'. . . (R)esults seem to indicate that . . . letter confusion . . . is likely to lead to the substitution of words differentiated from the correct ones only by the common vowels or the common ascenders." (p. 173)

D. Type faces.

- *. Some "writers recommend a simple, fairly broad type face, without great contrast between the thick and thin strokes." (p. 174) OLD FACE (e.g. CASLON) types "are to be preferred to MODERN FACE . . . . (A)esthetic opinion nowadays is in favour of OLD STYLE or OLD FACE . . . . This may . . . be merely a matter of fashion, similar to the fashion for BASKERVILLE and BODONI MODERN faces in the last century. It has (the) practical justification . . . that the very fine serifs and hair lines of a MODERN FACE type are liable to get broken, or to print off so badly as to be almost invisible; hence in part the illegibility of linotype newspaper print." (p. 174)
- *. "Javal recommended that OLD STYLE type should be used for children . . . . For adults, however, MODERN styles are preferable, since the total word form is more differentiated, by the alternation of main strokes and hair lines. But the long narrow serifs of MODERN faces tend to run into one another, and the OLD STYLE triangular serifs are more legible and durable." (p. 174-175)
- *. "Pyke . . . found that, on the whole, an OLD STYLE type face was the most legible. He concluded . . . that the ideal type 'should be simple, fairly broad, with fairly thick limbs, but not too much contrast in thickness and thinness, and with fairly wide spacing.'" (p. 175)
- *. "(N)ot much is known definitely as to the influence of typographical factors upon the ease and efficiency of reading. As long as the existent methods of experimentation are employed, it seems unlikely that conclusions of importance

will be reached." (p. 175)

Two general conclusions seem to predominate as a result of the author's review:

1. "In adult reading, in general only a small part of the visual field (is) actually perceived, probably only the contours of the words together with a few prominent details; these (are) sufficient to suggest the corresponding language and thought units, and hence to convey the meaning of the content." (p. 177)
2. "(T)he criterion of legibility should be based upon the reading of children. Type which is suitable for them will hold no difficulties for the adult, though certain modifications, such as reduction in size, may be found desirable." (p. 165)

* * *

2210 Vernon-1948

Vernon, Magdalen D.
THE PROBLEM OF THE OPTIMUM FORMAT FOR SCIENTIFIC JOURNALS. SUGGESTIONS AND POINTS FOR FURTHER INVESTIGATION
Paper No. 11 in THE ROYAL SOCIETY SCIENTIFIC INFORMATION CONFERENCE, 21 Jun-2 Jul 48, Report and Papers Submitted, (London, The Royal Society, 1948), p. 349-351

Problem: Report on optimum typographic considerations for characters and symbols to be used in scientific journals.

Procedure: Although no citations are appended to or referenced in the paper, it is apparent that the author's dissertation is based, at least in part, on previous experimental studies. However, since "there are large gaps in our knowledge as to the most legible formats . . . (statements concerning) (t)hese . . . have been selected mainly on the basis of . . . individual . . . opinion, rather than from the results of scientific experiments." (p. 351)

Result: The following points were made concerning the influence of typography, layout, and format on legibility and readability:

1. Type face - "In general, the most legible . . . are those to which the reader is most accustomed."
2. Character design - "(L)etters should be broad, medium bold, and not too much contrast between thick and thin strokes, and with short fairly thick serifs. TIMES ROMAN is a good example . . . ."
3. Face style - "Italics are less legible than roman letters, although they are sometimes useful" for contrast.
4. Letter height - "(O)ptimum type size is 10 to 12 point."
5. Interlineage - "(A) 2 or 3 point leading (is) the optimum."
6. Line length - It "should not exceed 10 cms."
7. Columns - "With double(s) . . ., there should be adequate white space or a vertical line between . . . ."
8. Margins - "Adequate (ones) are . . . desirable, particularly on the inside of the pages . . . ."
9. Contrast direction - "Black . . . on white . . . gives greater legibility than any other combination of colours."
10. Layout - Because of eye movement habits, "the layout . . . should attract the eye and distract the attention as little as possible."
11. Formulae - "(M)ake numbers, formulae, etc., stand out to some extent from the text . . . . On the other hand, they should not be made so arresting (for instance . . . in CLARENDON type) that they attract . . . from some quite different part of the text."
12. Character design for formulae - "(T)he most legible letters and digits, . . . in numbers and formulae, are . . . fairly broad, with bold black outlines, no

narrow hair lines, broad white inner spaces, clearly printed serifs, and (e.g. with c, e, E, F, 6, and 9) with wide 'gaps' between the ends of the outlines."

13. Illegible characters and symbols in formulae - The following letters, digits, and signs "are relatively illegible, and should when possible be thickened": i, j, l (el), t, 1 (one), +, -, and =.
14. Simplicity of symbols - "(S)implicity of outline, as in the O and Δ signs, makes for good legibility."
15. Character styles in formulae - "GREEK letters and italic letters and digits---and particularly exponents and subscripts---tend to be very illegible; . . . see that they are as black and as clear as possible. Particularly the parts which differentiate them from one another must be clearly shown; for instance the tail of 'σ' should be lengthened."
16. Formulae character grouping outline - "Formulae containing ascending letters ('b', 'd', 'h', etc.) and descending letters ('g', 'p', 'q'), fractions, capital letters and mathematical signs are more legible than those made up entirely of short letters, since the shape and outline of the former is more diversified and less homogeneous."
17. Numeral faces - "It seems possible that OLD FACE digits, which project above and below the line, are more legible than modern face digits which do not. . . (M)odernized OLD FACE digits should be used for mathematical tables, and . . . white space should be used to separate columns . . . ."
18. Numeral size - "(S)maller numbers with enough white space round them are superior to larger sized numbers."
19. Interpolated information - "(T)abular material and diagrams should be placed as close as possible to that part of the text to which they refer." Also, "adequate white spaces should be left between interpolated material and the body of the text, and also between columns of figures . . . ."
20. Footnotes - They "are tiresome . . . and should be avoided as far as possible."

The author, in addition, suggests the following concerning future experimental investigation:

1. "Probably the conclusions as to relative legibility should be based, not upon relative speed of reading, but upon relative accuracy of retention of the information given."
2. Subjects "should be of the type for whom the material is ultimately intended . . . (A) format which is most legible for one class of reader is not necessarily most legible for another." (quoted material in the preceding was taken from p. 349-351)

* * *

3370 Warren-1942
Warren, Alice L.
Minnesota U., Minneapolis
THE PERCEPTIBILITY OF LOWER CASE AND ALL CAPITALS NEWSPAPER HEADLINES
Master's Thesis, Nov 42, 71p., 28 refs.

Problem: In a "comprehensive study of typography.". . (p. 3), Paterson and Tinker "recommended that all capitals printing be eliminated from all text material, and also from newspaper headlines and other situations where 'speed of perception is especially important'." (p. 3) Whether Paterson and Tinker, who had used the normal reading situation in arriving at the above conclusions, were correct in these conclusions was challenged by Theodore M. Bernstein of the New York Times. Bernstein pointed out that "the readability of headlines is typically a matter, not of 'legibility' . . . , but of . . . 'perceptibility'" (p. 3) at more than the normal reading distance of 10 to 16 inches, "and that there are no grounds for assuming lower case to be superior to upper case under such conditions." (p. 3) Thus, this study was undertaken to determine "(t)he relative perceptibility of lower case and all capitals type . . . in single-column (and banner) headlines." (p. 40)

Procedure: "Fifty(, five-word) headlines of each type form . . . were presented .". . (p. 40) for the single-column-head test in 24-point size at 5-1/2 feet by means of the Whipple Disc Tachistoscope, and for the banner-head test in 60-point size at approximately 6 to 17 feet by the short-exposure (1 second) method. Stimuli for the single-column-head test "were printed on newsprint in . . . CHELTENHAM BOLD FACE EXTRA CONDENSED type in two-line single-column form .". . (p. 17) and for the banner-head test "in one-line multi-column . . . in MEMPHIS BOLD FACE . . . ." (p. 25) Forty (male and female) university student subjects participated in the single-column-head test, and 46 of the same in the banner-head test.

Result: In the single-column-head test, "the headlines proved equally perceptible when seen in lower case and in all capitals." (p. 40) In the banner-head test, the following results were seen: "At a distance of approximately six to eight feet, upper case was inferior . . . by 5.3 per cent. At nine and ten feet, upper case was superior by 2.6 per cent, and at thirteen to fourteen feet by 4.8 per cent. (p. 40) At sixteen to seventeen feet, upper case was 19.8 per cent more perceptible . . . The conclusion drawn . . . is that the relative perceptibility . . ., for any given type size, depends upon the distance . . . . Lower case is more perceptible at shorter distances, due to its more marked work form; upper case . . . at greater distances due to the larger size and heaviness of its letters. At some point . . ., the two type forms are equally perceptible. . . In view of the short distances at which single-column headlines usually are read, it is recommended that they be set in lower case. . . Banner headlines, however, are glimpsed under a wide variety of circumstances." (p. 41) Because of this, "it is concluded that as far as perceptibility is concerned(,) one type form is as satisfactory for this use as the other." (p. 41)

* * *

3316 Whiteside-1951
Whiteside, T. C. C., and Roden, T. G. V.
RAF Inst. of Aviation Medicine (Gt. Brit.)
VISIBILITY OF AERODROME SYMBOLS OF ICAO - NEW ISSUE RAF AND MODIFIED NEW RAF MAPS
Rept. no. FRRC 760, May 51, 5p.
ATI-116 385

Problem: Test "(t)he comparative visibility of ICAO, NEW ISSUE RAF and MODIFIED RAF aerodrome symbols on maps . . . by 'normal reading intensity' electric lights." (p. 1)

Whiteside-1951

Procedure: "Three types of aerodrome symbols were examined: ICAO in red, RAF in black, and MODIFIED RAF (center filled in and symbol in black) . . . . Map sheets of three areas were used, all the symbols on one map being of one type." (p. 1) Under illumination "provided by a 100 watt daylight (blue) bulb, 26 inches above the near edge of the sheet so as to give no specular reflections . . . (, ) (p. 2) subject(s were) shown map "A" under a perspex (clear plastic) sheet and told to tick off in 15 seconds as many aerodromes as possible. (They) then repeated the performance with map(s) 'B' . . . and . . . 'C'." (p. 1)

Result: "The hypothesis . . . that there was no significant difference between reading RAF NEW ISSUE and ICAO map (symbols). . . was disproved. . . (p. 2) The MODIFIED NEW RAF symbols were easiest of all to see; the ICAO red symbols were easier to see than the NEW ISSUE RAF black symbols. The difference in score was largely due to the loss of colour contrast in the NEW RAF map. To increase visibility it was recommended:-

1. "That aerodrome symbols . . . should be modified as suggested.
2. "That if this could not be done, printing the symbols in electric blue would ensure good visibility by red light, although the degree of visibility attained might still not be up to the level of that of ICAO symbols, as in the NEW RAF series the level of colour contrast produced by electric blue against a purple background would probably be less than that obtained by printing electric blue against the brown background of ICAO hypsometric tints.
3. "That where electric blue is used for aerodrome symbols on RAF maps it should be richly printed in a hue quite distinct from sea blue or the purple of the hypsometric tints.

"In view of th(e) findings . . . (, i)t has been possible . . . to reduce slightly the diameter of the (MODIFIED RAF) symbols to save map space." (p. 1)

* * *

2250 Wright-1958a

Wright, Natalie L., and Seminara, J. L.
Picatinny Arsenal, Dover, N. J.
READABILITY THRESHOLDS OF LETTERS AND NUMBERS BACKLIGHTED BY RADIOACTIVE ILLUMINANTS
Technical rept. 2471, Mar 58, 36 p., 7 refs.

Problem: "(D)etermine optimum colors, brightness levels, and letter sizes in connection with the use of radioactive self-luminous compounds to backlight panel markings." (p. 1)

Procedure: "Radioactive (Strontium-90*) illuminants of 3 colors and 5 brightness levels (10.8 effective microlambert green, 13.2 . . . yellow, 17.6 . . . blue, 26.6 . . . green, and 28.8 . . . yellow) were used to backlight 4 sizes (0.116-, 0.170-, 0.184-, and 0.235-inch high LEROY characters)** of words (FUZE, FIRE, HIGH, STOP, and DOWN), numbers (13, 237, 15, 18, and 689), and nonsense syllables (YAD, VOB, SEG, PAM, KIJ, LUS, RON, WOF, ZUT, and BIP). . . Readability thresholds were established by moving a board bearing the back-lighted . . . (stimuli) toward and away from a subject (of five) who was instructed to declare when he could just accurately read and . . . not read the(m) . . . ." (p. 1)

Result: "The 28.8 effective microlambert yellow was found to be most readily readable. The blue illuminant was definitely inferior . . . Dark lettering against an illuminated background (was found to be) undesirable for night time panel markers since too much light is given off. However, since black on white has been shown to provide the best contrast for legibility when outside light sources are used, a part of this study . . . was

devoted to a comparison . . . (p. 1 & 8) No significant difference was found between the thresholds for dark- . . . and . . . light-adapted subjects. . . Of the colors used . . ., yellow on a black background yield(ed) the best readability thresholds. . . (T)he particular half life of the . . . isotope . . . (was) taken into consideration . . . ." (p. 1) Source to eye transmission loss was also computed. It was noted that "(w)henever radioactive self luminous sources are considered for use in equipment which will be subjected to a great deal of vibration, suitable tests should be performed to ensure that the protective shielding remains adequate despite the loosening effects of the vibration." (p. 2) This safety consideration is in addition to considerations of legibility loss caused by the vibration. And finally, there was an "indicat(ion) that color is a more important variable than intensity within the (same) range of brightnesses . . . ." (p. 17) There were significant second order interactions between adaptation and subjects, types of stimuli and subjects, and letter size and brightness. The only significant third order interaction involved adaptation, type of stimuli, and subjects. In conclusion, the following "tentative" brightness values for panel markings of various sizes and colors were recommended:

| character height | yellow | green |
|---|---|---|
| 0.116 inch | 33 effective microlamberts | 55 eff. μL |
| 0.170 inch | 20 eff. μL | 35 eff. μL |
| 0.184 inch | 18 eff. μL | 31 eff. μL |
| 0.235 inch | 9 eff. μL | 16 eff. μL |

(above from p. 23)

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* The authors note that "(t)he use of strontium-90 compounds is . . . limited to situations which permit the extra space and weight of shield(ing). . . Sources which are excited by . . . newly developed radioisotopes (e.g. tritium and kryston) . . . offer a grea(t) range of colors . . ., are eas(y) to apply . . . (, and) require little shielding to prevent external radiation." (p. 3 & 4)

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** Additional dimensions of characters were as follows (stroke width being the least consistent dimension because of variance in the amount of ink on the pen):

| dimension | sizes | (in inches) and ratios | | |
|---|---|---|---|---|
| height | 0.116 | 0.170 | 0.184 | 0.235 |
| width | 0.089 | 0.124 | 0.136 | 0.176 |
| stroke width | 0.016 | 0.019 | 0.021 | 0.034 |
| stroke width/height | 1/7 | 1/9 | 1/9 | 1/7 |
| width/height | 3/4 | 3/4 | 3/4 | 3/4 |

* * *

3342 Wright-1958b

Wright, Natalie L.

Picatinny Arsenal, Dover, N. J.

A STUDY OF LEGIBILITY CONCERNING THE INTERACTION OF LETTER DESIGN WITH THE COLOR AND BRIGHTNESS OF TRANSILLUMINATION

Technical Memorandum 132, Oct 58, 31 p., 13 refs.

Problem: "(D)etermine the best practical combination of letter design and transillumination for optimum legibility at a distance of 28 inches." (p. iv)

Procedure: "Red and yellow self-luminous (radioactive---Strontium 90) sources in low level brightnesses backlighted AND 10400 (height to width ratio equals 3:2, except A, I, N, and W) and AMEL (height to width ratio equals 1:1, except I, J, and L) style capital letters,

3/16 inch high.". . (p. iv) and having stroke-widths 1/6 and 1/8 the height, "were presented individually, in a dark room, with time and number of errors as the criteria. . . (p. iv) One male and one female subject . . . were used." (p. 9)

Result: The following results were seen:

1. "Red self-luminous letters provide(d) better visual acuity than (did) yellow (with) the background . . . black, the viewing distance . . . 28 inches, and . . . the two colors . . . of equal brightness. This pertains . . . to brightnesses calibrated by photometric, subjective methods. . . (p. 19) (I)t appears that a more rigid standard (of calibration) is necessary.". ., (p. iv) however. Also, "(w)hen a self-luminous radioactive source is used, the half life of the phosphor . . . must be considered. . .(, usually) requir(ing) a 55 (microlambert) . . . source at the time of manufacture.". . (p. iv) in order to give an approximately 14 microlambert brightness at the normal expiration of equipment shelf-life.
2. "That letter style, AMEL design with a (height of 3/16 inch and a) stroke width 1/6 the height, which . . . (p. 19) supplie(d) excellent transillumination. . . (p. iv) (and) was best at 14 (microlamberts), was also best when the brightness was increased by a factor of four." (p. 19)
3. "The AMEL letters were definitely easier to read than the AND (10400). Both style and equal height to width ratio appear to be important in providing better acuity." (p. 19)
4. "At lower levels of brightness, acuity was definitely better with a 6:1 stroke width. It was not a disadvantage when the brightness was increased. Therefore, a 6:1 ratio should be used." (p. 19)
5. "Four letters were errorless--the 'A, I, R, and Z.' The 'G', the only letter which was worse in the AMEL style, should have a larger opening and an extended bar. The 'Q' was very poor in the AND (10400) style, probably because of a poorly defined bar. . . (p. 19) (A)n order of preference has been worked out for letters to be used in coding: A Z L N E V R W M X P T J Y U H K S B F I D C Q O (and) G(.)

   This order is based on time-to-read and errors and has not been tested for efficiency when combined with numbers." (p. 18)
6. "Color, brightness, and style were the important interactions, both two-way and three-way. Brightness significantly (sic) interacted with stroke width, meaning that a wider stroke was preferable at lower brightnesses. There was a significant difference between subjects and color, too, due to the fact that one subject responded better to yellow than did the other . . . ." (p. 19)

In addition, the following recommendations for the design engineer were specifically delineated (somewhat repetitious of the results shown above):

"A. Lettering for Transilluminated Panels

1. Lettering should be all capitals, 3/16 inch high. (Capital, rather than lower case, lettering is generally recommended in the literature.) (sic)
2. The style should be the AMEL block design or one similar to it which has a height to width ratio of 1:1. (In the AMEL style, the 'J' and 'L' are in a 12:9 ratio.)
3. If possible, two letters in the AMEL style should be changed slightly to improve acuity. The 'G' should have a larger opening in the circle, and the bar should be extended to the left to the center of the circle. The bar through the bottom of the 'Q' should be extended upward. . .
4. The stroke width should be 1/6 the height.
5. When letters are used for coding purposes, i.e., not combined in words, avoid using the 'G, Q, O, and C' whenever possible.
6. The space between the letters probably should be about one-half the letter width. If space is limited, the distance could be less between those letters whose outside strokes are not parallel, e.g. 'A' and 'T' and 'B', but not 'U' and 'D' and 'E'. Since this study tested one letter at a time, no empirical

evidence is available.

"B. Transillumination

1. When self-luminous sources are to be used, they will probably be calibrated by the manufacturer by some subjective photometric method. Where these methods are employed to measure the level of brightness, red illumination is recommended for backlighting the above letter design. The surrounding area should be black.
2. The illuminants should have a brightness of no less than 10 and no more than 55 microlamberts. At the end of the 20-year shelf life, the brightness should be no less than 10 (microlamberts) so, depending upon the half life of the phosphor used, the installed source must be between 40 and 55 (microlamberts).
3. Any material which is placed between the light source and the observer must be taken into consideration. The film on which the letters were printed for this experiment cut out 15 per cent of the light. This should be known so that the correct brightness can be chosen." (p. 20-21)

* * *

2251 Young-1946

Young, Katherine D.
Engineering Div., Air Materiel Command,
Wright-Patterson Air Force Base, Ohio
LEGIBILITY OF PRINTED MATERIALS
Memorandum rept. no. TSEAA-8-694-1A,
10 Jun 46, 27 p., 24 refs.
ATI-110 570

Problem: "(S)ummarize experimental studies on legibility of printed materials." (p. 1)

Procedure: "Studies . . . concerned with discovering the conditions under which printed material is best suited to the capacities and habit patterns of the average person. . . (,) published in the psychological literature . . . on legibility . . ., have been reviewed. The most important of these studies (which are primarily the work of Paterson and Tinker) are summarized in the Appendix to this report." (p. 1)

Result: The following conclusions and recommendations were shown:

1. "Under ordinary reading conditions, type faces in common use are equally legible, as measured by speed of reading. However, material printed in AMERICAN TYPEWRITER, ANTIQUE, CHELTENHAM, and OLD STYLE type can be read accurately at a greater distance than can . . . CLOISTER BLACK, KABEL LIGHT, SCOTCH ROMAN, or BODONI." (p. 1) Thus, it is recommended "(t)hat any commonly used type face be used for printed material, which is to be read under ordinary conditions, but that if the material must be read at considerable distance," (p. 2) the above first mentioned faces should be used.
2. "When size of type is studied as an isolated factor, 10 point type, measured by visibility and speed of reading, seems to be the most legible under ordinary reading conditions. This can be varied from 8 to 12 point without seriously retarding speed of reading." (p. 1)
3. "When type size is kept constant at 10 point, and line length is studied as an isolated factor, 80 (millimeters) (19 picas) is found to be the optimum line length for greatest speed of reading. . . The factors of line length and size of type must be properly balanced, as neither one alone can be relied upon in determining optimum typographical arrangements." (p. 2) It is recommended "(t)hat 8, 9, or 10 point type be used with 17, 18, or 19 pica line width respectively for ordinary reading situations." (p. 3)
4. "Material printed in lower case is much more legible, as measured by speed of reading than material printed in capitals. Single words printed in capitals are perceived at a greater distance than words in lower case." (p. 2) From this, it is recommended "(t)hat the use of all capitals be eliminated from headlines as well as from text, and from signs and markers except where perceptibility at the greatest possible distance is essential." (p. 3)
5. "Material printed in lower case (roman) is read, under normal reading conditions, somewhat faster than that printed in italics." (p. 2) Thus, it is recommended "(t)hat the use of italics be restricted to short passages when needed for contrast or emphasis." (p. 3)
6. "The legibility of words and letters printed in black type on white background is greater than that of white on black." (p. 2) It is recommended "(t)hat white print on black background be used only for a small amount of text when contrast is desired as an attention-getting device. . . (, but is to) be avoided for distance reading and where possible for instrument panels, labels, and signs." (p. 3)
7. "When colored print on colored background is used, brightness contrast between print and background is necessary for good legibility." (p. 2) Thus, ". . . combinations of colors used for print and background (should) be chosen for maximum brightness contrast." (p. 3)

8. "Variations in paper surface have little effect on the legibility of printed material. If glossy surface tends to retard reading, the retardation is offset by the clearer white of the paper and the sharper printing impressions on the glossy surface. The amount of glaze permissible depends upon the type of illumination used." (p. 2)
9. "Leading is a factor in good legibility, but its influence varies with the size of type used." (p. 2)
10. "Measured by speed of reading, legibility of material is not affected by width of margin." (p. 2)
11. "Speed of reading and clearness of seeing (fatigue) measures indicate that the minimum level of illumination for 10 point type is between 3 and 10 foot-candles. Measured by speed of reading, the minimum . . . for . . . 7 point type is between 15 and 20 foot-candles." (p. 2)
12. "In isolation, OLD STYLE numerals are somewhat easier than MODERN to perceive at a distance, and in groups they are much easier to perceive. When by speed of reading, MODERN numbers are read as fast as OLD STYLE." (p. 2) Yet, it is recommended "(t)hat OLD STYLE numerals be used rather than MODERN." (p. 3)

* * *

# APPENDIX A: AUTHOR INDEXES

(alphabetical and chronological)

## AUTHOR INDEX (alphabetical)

* note: upon review, the works reported upon by Hogg-1957 and Kimura-1959 appear to be similar and by the same experimenter---the former name is possibly née.

* * *

AUTHOR INDEX (chronological)

* * *

# APPENDIX B: CHARACTER FACE NAME INDEX

## CHARACTER FACE NAME INDEX

There are three types of entries in the following Character Face Name Index. These are as follows: (1) CHARACTER FACE name to Document Extract identification (e.g., VOGUE: Bendix-1959, Brown-1953, and Longyear-1936); (2) Document Extract identification to CHARACTER FACE name (e.g., Paterson-1946a: See BOLD faces, CHELTENHAM, and MEMPHIS); and (3) cross-references of various kinds. All of the above are intermingled together in letter-by-letter alphabetical sequence. Following the alphabetic sequence are the names, in number-by-number order, of eight character faces whose names begin with a number.

In addition, several peculiarities should be explained in that they might otherwise cause difficulty in the use of this Index. (1) The spelling of foreign face names does not necessarily coincide with the spelling of the language for which it is used (e.g., MALAYALIM versus Malayalam). (2) In the case of face names whose acronym is more commonly known than the spelled-out version, the acronym is underlined and cross-referenced to the full spelling (e.g., AMEL: See Aero-Medical Equipment Laboratory). However, when the face name has been superseded by another, the older version is not underlined, and cross-reference is made to the new name (e.g. AND 10400 versus MS 33558). Nonetheless, appropriate citations are listed for both. (3) Several face names are followed by a parenthetical comment. This was done to identify, when it was not entirely clear from the face name, the medium in which the face is used (e.g. COMPOSITRON (display), in this case connoting use in a display medium other than that commonly encountered in printed text (e.g., cathode-ray tube displays). (4) Some underlined names are followed by such names as for example "symbols," "faces," "forms," etc. (e.g., MACHINE RECOGNITION faces). These entries cover classes of, rather than individual, character faces. In some few cases, "class" names are made to stand alone since they are attributed sometimes to a face name but usually are descriptive of some special condition, as configuration, of the face (e.g., ITALICS). (5) As noted below in a fuller listing, there also exist special entries, such as UNSPECIFIED COMMERCIAL and UNSPECIFIED EXPERIMENTAL faces.

These entries are as follows: BLOCK style (otherwise unspecified), BOLD faces, BOLD FACE SERIES (listed here as an example of the fact that type face series numbers are not usually listed in this Index, unless the number is the only identification, in which case it is listed under NO. ...), CALIGRAPH/CUNEIFORM/HIEROGLYPHIC faces (listed here to indicate those classes of faces in which symbols are used in pictorial

language form), CONDENSED faces, DIACRITICAL MARKS (PUNCTUATION), EMBOSSED faces, EXPANDED/EXTENDED/WIDE faces, GOTHIC (GROTESQUE, SANS, SANSERIF, SANS SERIF, SANS SERIFFED, etc.) faces, GROUNDWORK, HANDWRITING (hand-written/-printed---see also SCRIPT), HATCHED (CHECKED) faces, INITIALS (various), IRREGULAR symbols (including FAMILIAR and GEOMETRIC forms, ARBITRARY shapes, PICTORIAL, ABSTRACT, and DISTORTED figures, etc.---either LINE or SOLID), ITALICS (including OBLIQUE faces and INCLINED/SLANT GOTHIC), KERNED characters, LIGATURES, LIGHT faces, LINING faces (see LINING, INLINE, OUTLINE, and SKELETON faces, individually), MACHINE RECOGNITION faces (machine recognition, magnetic and optical characters), MATRIX/ELEMENT faces, MODIFIED faces, NEWSPAPER faces (otherwise unspecified), NOVELTY faces (otherwise unspecified), OLD ENGLISH (includes, e.g., BLACK-FACE, TRADITIONAL GOTHIC, and several others), OPEN style (otherwise unspecified), OPTICAL ILLUSIONS, ORNAMENTAL faces, OVAL style (otherwise unspecified), PECULIARS, RECTANGULAR faces, REVERSED faces, ROUND style (otherwise unspecified), SCRIPT (handwriting and printing), SEMICIRCULAR faces, SHORTHAND, SUB- and SUPER-SCRIPTS, SWASHES, SYMBOLS (various---composite listing at this entry and individual listings throughout Index, e.g. BOTANICAL symbols), TRIANGULAR faces, TYPEWRITER (otherwise unspecified), UNSPECIFIED COMMERCIAL faces (various), and UNSPECIFIED EXPERIMENTAL faces (various).

A (experimental): Botha-1963a and also see BOTHA.

ABBEY TEXT: Legros-1916.

ABKHAZIAN: Legros-1916.

ABSTRACT figures: See IRREGULAR symbols.

ACCADIAN CUNEIFORM: Legros-1916.

ADDRESSOGRAPH: Legros-1916.

(Aero-Medical Equipment Laboratory) AMEL: Atkinson-1952, Crook-1954c, Harris-1956, Swartz-1961, Wright-1958b, and also see NAMEL.

AGATE: Rose-1946.

AIR FORCE (machine recognition): Flores-1960.

AIRPORT: Bendix-1959 and Brown-1953.

ALBANIAN: Legros-1916.

Aldrich-1937: See BLOCK style, EMBOSSED faces, OPEN and ROUND styles, and VERMONT 1937.

Allen-1955: See BPR SERIES.

Alluisi-1957: See AND 10400; MATRIX/ELEMENT faces; and 8-ELEMENT, STRAIGHT-LINE MATRIX.

Alluisi-1958: See AND 10400; MATRIX/ELEMENT faces; and 6-ELEMENT, STRAIGHT-LINE MATRIX.

ALPHADYNE (display): Crumley-1961.

ALTERNATE GOTHIC: See TYPEMASTER.

AmASHO-1961: See UNSPECIFIED EXPERIMENTAL faces.

AMEL: See Aero-Medical Equipment Laboratory.

AMERICAN CASLON: Longyear-1936.

AMERICAN GOTHIC: Bendix-1959.

AMERICAN NUMBERING-MACHINE: Legros-1916.

(American Standards Association) ASA (Optical Character Recognition) OCR (machine recognition): Rabinow-1962.

AMERICAN TYPEWRITER: Blackhurst-1927, Chapanis-1949, InsTUFTS-1952, Paterson-1940a, Poulton-1960, Tinker-1944, Tinker-1963, and Young-1946.

AMHARIC: Legros-1916.

AMOY: Legros-1916.

ANCIENT: Legros-1916.

ANCIENT SLAVONIC: Legros-1916.

Anderson-1960: See BANKERS GOTHIC, E13B, and MACHINE RECOGNITION faces.

AND 10400: See Army-Navy Drawing.

ANGLO-SAXON: Legros-1916.

ANNAMITE: Legros-1916.

ANTIQUE: Chapanis-1949, InsTUFTS-1952, Legros-1916, Paterson-1940a, Tinker-1944, Tinker-1963, TinkPat-1944b, and Young-1946.

ANTIQUE OLD STYLE: Legros-1916.

ARABIC: Legros-1916.

ARBITRARY shapes: See IRREGULAR symbols.

ARCHEOLOGICAL symbols: Legros-1916.

ARMENIAN: Legros-1916.

(Army-Navy Drawing) AND 10400: Alluisi-1957, Alluisi-1958, Atkinson-1952, Baker-1954, Bendix-1959, Brown-1951, Colgate-(1955), Crannell-1958, Crook-1951, Crook-1954c, Harris-1956, Schapiro-1952, Slivinske-1957, Swartz-1961, Wright-1958b, and also see MS 33558.

ArmyWES-1953: See BOLD, CONDENSED, and EXPANDED/EXTENDED/WIDE faces; ITALICS; LIGHT faces; and WRICO.

ARPKE: Ovink-1938.

ARROW symbols: Bauch-1954, Legros-1916, and Smith-1958.

ARTYPE: Bendix-1959.

ARTYPE S-274: See NAMEL.

ASA OCR: See American Standards Association.

ASHANTI: Legros-1916.

ASSYRIAN: Legros-1916.

ASSYRIAN CUNEIFORM: Legros-1916.

ASTREE: Longyear-1936.

ASTRONOMICAL symbols: Legros-1916.

Atkinson-1952: See AMEL, AND 10400, and BERGER.

ATLAS: Legros-1916.

AUGUSTAN BLACK: Legros-1916.

AUTOMATIC CHARACTER RECOGNITION: See MACHINE RECOGNITION faces.

B (experimental): Botha-1963a and also see BOTHA.

BABYLONIAN: Legros-1916.

BABYLONIAN CUNEIFORM: Legros-1916.

Baker-1954: See AND 10400 and NAMEL.

BANKERS GOTHIC: Anderson-1960 and Bendix-1959.

BANK GOTHIC: Bendix-1959.

BARNUM: Longyear-1936.

BARTLETT: Murrell-1952.

BASKERVILLE: Burt-1959 and Vernon-1931.

BATTA: Legros-1916.

Bauch-1954: See ARROW symbols, GOTHIC faces, and SYMBOLS.

Bauer-1962: See MATRIX/ELEMENT faces and 5 X 7 MATRIX.

BELL: Burt-1959.

BEMBO: Burt-1959 and Ovink-1938.

Bendix-1959: See AIRPORT, ALTERNATE GOTHIC, AMERICAN GOTHIC, AND 10400, ARTYPE, ARTYPE S-274, BANKERS GOTHIC, BANK GOTHIC, BERGER, BLOCK style, BOLD faces, CLASSIC ROMAN, COMMERCE GOTHIC, CONDENSED faces, COPPERPLATE GOTHIC, EXPANDED/EXTENDED/WIDE faces, FRANKLIN GOTHIC, FUTURA, FUTURA BOOK, FUTURA DISPLAY, GORTON, GORTON MODERNE, GOTHIC faces, HEADLINER, LABEL GOTHIC, LEROY, LIGHT faces, LINING GOTHIC, LINING METROTHIN, LINING PLATE GOTHIC, MACKWORTH, MARAN GOTHIC, METROBLACK, METROLITE, METROTHIN, MIL-C-18012, MODERNE, MS 33558, NAMEL, NEWS GOTHIC, OLD ENGLISH, OPEN style, ORNAMENTAL faces, PHILADELPHIA LINING, PHOTOTYPE, PLATE GOTHIC, RECTANGULAR faces, ROMAN, SANS SERIF, SEMICIRCULAR faces, SPARTAN, SPARTAN BLACK, SPARTAN BOOK, SQUARE GOTHIC, TEMPO, TOURIST, TRADITIONAL GOTHIC, TRIANGULAR faces, TWENTIETH CENTURY, TYPEMASTER, UNSPECIFIED COMMERCIAL and EXPERIMENTAL faces, VARITYPE, VERNEN, and VOGUE.

BENGALI: Legros-1916.

BERGER: Atkinson-1952, Bendix-1959, Berger-1944b, Berger-1948, Berger-1950, Berger-1952, Berger-1960, Brown-1951, Chapanis-1949, Colgate-(1955), Crook-1954c, Harris-1956, Krulee-1954, Krulee-1955, Murrell-1952, Schapiro-1952, and Swartz-1961.

Berger-1944b: See BERGER; BOLD, EMBOSSED, and LIGHT faces; OLD DANISH; and 2 and 6 MILLIMETER STROKE-WIDTH.

Berger-1948: See BERGER, and GOTHIC faces.

Berger-1950: See BERGER, and GOTHIC faces.

Berger-1952: See BERGER, and GOTHIC faces.

Berger-1956: See REGAL and WEISS.

Berger-1960: See BERGER; DOT, IRREGULAR, and PARALLEL BAR symbols; and SYMBOLS.

Berger-1961: See MOSAIC-STRUCTURE and UNSPECIFIED EXPERIMENTAL faces.

BERNHARD CURSIVE: Longyear-1936 and Ovink-1938.

BERNHARD FASHION: Longyear-1936.

BERNHARD ROMAN: Longyear-1936 and Ovink-1938.

BETON: Longyear-1936 and Ovink-1938.

Betts-1942: See CENTURY OLD STYLE.

BINNEY: Longyear-1936.

Birren-1957: See BPR SERIES.

BISAYA: Legros-1916.

Bitterman-1945: See UNSPECIFIED COMMERCIAL faces.

Bitterman-1946a: See UNSPECIFIED COMMERCIAL faces.

Bitterman-1946c: See UNSPECIFIED COMMERCIAL faces.

Bjelland-(1963): See DOT MATRIX, LINE TRACE, MATRIX/ELEMENT faces, and SHAPED BEAM.

BLACK: Legros-1916.

BLACK-FACE: See OLD ENGLISH.

BLACKFRIARS: Legros-1916.

Blackhurst-1927: See AMERICAN TYPEWRITER, CUSHING MONOTYPE, JENSEN OLD STYLE, and SCOTCH ROMAN.

BLACK-LETTER: See OLD ENGLISH.

BLIP symbols: Crumley-1961.

BLOCK style (otherwise unspecified): Aldrich-1937, Bendix-1959, Bridgman-1956, Legros-1916, and Uhlaner-1941.

BODONI: Burt-1959, Chapanis-1949, English-1944, InsTUFTS-1952, Longyear-1936, Luckiesh-1942, Ovink-1938, Paterson-1940a, Starch-1923, Tinker-1944, Tinker-1963, TinkPat-1944b, and Young-1946.

BODONI BOOK: Longyear-1936 and Luckiesh-1940b.

BODONI MODERN: Vernon-1931.

BODONI SHADED: Longyear-1936.

BOHEMIAN: Legros-1916.

BOLD faces: ArmyWES-1953, Bendix-1959, Berger-1944b, Breland-1944, Brown-1953, Burt-1959, Chapanis-1949, Chaundy-1954, English-1944, Foley-1957a, Foley-1957b, Kelly-1960, Legros-1916, Longyear-1936, Luckiesh-1940a, Luckiesh-1940b, Luckiesh-1942, Ovink-1938, Paterson-1940a, Paterson-1946a, Poulton-1960, Rowland-1958, Starch-1914, Starch-1923, Tinker-1963, TinkPat-1946b, and Warren-1942.

BOLD FACE SERIES: Chaundy-1954 and Longyear-1936.

BOOKLET: Legros-1916.

BOOKMAN: Longyear-1936 and Luckiesh-1942.

BORDER symbols: Legros-1916.

BOTANICAL symbols: Legros-1916.

BOTHA: Botha-1963a and Botha-1963b.

Botha-1963a: See A, B, and BOTHA.

Botha-1963b: See BOTHA, and UNSPECIFIED EXPERIMENTAL faces.

Bowen-1959: See CIRCULAR, CROSS, IRREGULAR, and SQUARE symbols; SYMBOLS; and TRIANGULAR symbols.

BPR SERIES: See Bureau of Public Roads.

BRAILLE: Legros-1916.

Brainard-1961: See ROAD SIGN symbols, and SYMBOLS.

Breland-1944: See BOLD faces and CHELTENHAM.

Bridgman-1956: See BLOCK style.

BROWN: Brown-1951, Brown-1953, Soar-1955b, and Soar-1958.

Brown-1949a: See GROW CHART.

Brown-1949b: See GROW CHART.

Brown-1951: See AND 10400, BERGER, and BROWN.

Brown-1953: See AIRPORT, BOLD faces, BROWN, FUTURA, GARAMOND, GOTHIC SANS-SERIF, LINING GOTHIC, UNSPECIFIED EXPERIMENTAL faces, and VOGUE MEDIUM.

BRUCE: Longyear-1936.

BRUCE OLD STYLE: Longyear-1936.

BRUSH SCRIPT: Longyear-1936.

BUGI: Legros-1916.

BULGARIAN: Legros-1916.

BULLFINCH: Hollingworth-1913, Starch-1914, and Starch-1923.

(Bureau of Public Roads) BPR SERIES A-F (display): Allen-1955, Birren-1957, BurPR-nd(a), BurPR-1958, BurPR-1961, Chapanis-1949, Decker-1961, Forbes-1951, Herrington-1960, Karmeier-1960, Solomon-1956, and Ullman-1958.

BURMESE: Legros-1916.

BurPR-nd(a): See BPR SERIES.

BurPR-1958: See BPR SERIES.

BurPR-1961: See BPR SERIES.

Burt-1959: See BASKERVILLE, BELL, BEMBO, BODONI, BOLD faces, CASLON, CENTAUR, DIDOT, EHRHARDT, FOURNIER, GARAMOND, GRANJON, IMPRINT, MODERN, OLD ENGLISH, OLD STYLE, PERPETUA, PLANTIN, SCOTCH ROMAN, TIMES NEW ROMAN, VERONESE, and WALBAUM.

CALIFORNIA (display): Smith-1958.

CALIGRAPH: Longyear-1936.

Carmichael-1947: See UNSPECIFIED COMMERCIAL faces.

CARSHUNI: Legros-1916.

CARTOGRAPHIC symbols: Legros-1916.

Case-1952: See UNSPECIFIED EXPERIMENTAL faces.

CASLON: Burt-1959, Chapanis-1949, Hollingworth-1913, Longyear-1936, Paterson-1940a, Starch-1914, Starch-1923, Tinker-1963, and Vernon-1931.

CASLON MODERN: Longyear-1936.

CASLON OLD FACE: Luckiesh-1942.

CASLON OLD STYLE: InsTUFTS-1952 and Tinker-1944.

Dixon-1948: See UNSPECIFIED EXPERIMENTAL faces.

Dodge-1907: See TYPEWRITER.

DOTITRON (display): Crumley-1961.

DOT MATRIX (display): Bjelland-(1963).

DOT symbols: Berger-1960, Cohen-1953, and Swartz-1961.

DUPLICATING MACHINE: Legros-1916.

DUTCH: Longyear-1936.

ECCLESIASTICAL: See OLD ENGLISH.

ECCLESIASTICAL GEORGIAN: Legros-1916.

ECCLESIASTICAL symbols: Legros-1916.

ECKMANN: Ovink-1938.

EGYPTIAN: Legros-1916.

EHRHARDT: Burt-1959.

ELBAR: Longyear-1936.

ELECTROLUMINESCENT ALPHANUMERIC DISPLAY (display): Crumley-1961.

ELEMENT fonts: See MATRIX/ELEMENT faces.

ELEMENT symbols: Cohen-1953 and Legros-1916.

ELITE GOTHIC (experimental): OptRead-1961.

ELITE TYPEWRITER: Luckiesh-1942.

ELLIPTICAL symbols: Casperson-1950, Crumley-1961, Sleight-1952, and Swartz-1961.

ELZEVIR: Legros-1916.

EMBOSSED faces: Aldrich-1937, Berger-1944b, Gleason-1947, Herrington-1960, Karmeier-1960, Legros-1916, Silver-1940, and Soar-1955b.

ENGINEERING symbols: Legros-1916.

ENGLISH: Rose-1946.

English-1944: See BODONI, BOLD faces, CHELTENHAM, CONDENSED faces, KARNAK, OLD ENGLISH, and TEMPO.

ENGRAVERS ROMAN: Longyear-1936.

Erdmann-1898: See UNSPECIFIED COMMERCIAL faces.

ESKIMO: Legros-1916.

ESPERANTO: Legros-1916.

ESTIENNE MORSE: Legros-1916.

ESTRANGELO: Legros-1916.

ETHIOPIC: Legros-1916.

EVE: Longyear-1936.

EXCELSIOR: Luckiesh-1942, Ovink-1938, Tinker-1946, Tinker-1948b, Tinker-1948c,

GILL: Chaundy-1954 and Krzhivoglavy-1962.

GIRDER: Longyear-1936.

Gleason-1947: See CIRCULAR symbols, EMBOSSED and LIGHT faces, PARALLEL BAR and POINTER symbols, SYMBOLS, and UNSPECIFIED COMMERCIAL and EXPERIMENTAL faces.

GLORIA: Longyear-1936.

GORTON: Bendix-1959.

GORTON MODERNE: Bendix-1959.

GOTHIC: See OLD ENGLISH.

GOTHIC faces: Bauch-1954, Bendix-1959, Berger-1948, Berger-1950, Berger-1952, Coffey-1961, Crook-1952, Crook-1954c, Flores-1960, Green-1953, Hulbert-1957, Krulee-1955, Lauer-1948, Legros-1916, Longyear-1936, Luckiesh-1923, Ovink-1938, and Vernon-1931.

GOTHIC SANS-SERIF: Brown-1953.

GOTHIC TEMPO: Deuth-1953.

GOUDY: Longyear-1936.

GOUDY CATALOGUE: Longyear-1936.

GOUDY HAND TOOLED: Longyear-1936.

GRANJON: Burt-1959, Paterson-1940a, Paterson-1943, and Tinker-1963.

GRASSET: Ovink-1938.

GRECO: Longyear-1936.

GRECO ADORNADO: Longyear-1936.

GREEK: Chaundy-1954, Legros-1916, and Vernon-1948.

Green-1953: See GOTHIC faces.

GROTESQUE: See GOTHIC faces.

GROUNDWORK: Legros-1916.

GROW CHART: Brown-1949a and Brown-1949b.

GUARANI: Legros-1916.

GUJARATI: Legros-1916.

Gustafson-1960: See COLOR symbols, and SYMBOLS.

Halsey-1960a: See MATRIX/ELEMENT faces and 5 X 7 MATRIX.

Halsey-1960b: See CHANGING symbols, SAGE, and SYMBOLS.

HANDWRITING (hand-written/-printed): Chaundy-1954, InsTUFTS-1952, Luckiesh-1942, Neisser-1960, Soar-1955a, Starch-1923, Tinker-1963, and Vernon-1931.

HARMONIC (display): Crumley-1961.

Harris-1956: See AMEL, AND 10400, BERGER, CHARACTRON, LEROY, LINCOLN LABORATORY, MACKWORTH, and MATRIX/ELEMENT faces.

Hastings-1956: See COLOR symbols.

HATCHED faces: Legros-1916.

HAWARDEN: Legros-1916.

HEADLINER: Bendix-1959.

HEBREW: Legros-1916.

HERALDIC symbols: Legros-1916.

Herrington-1960: See BPR SERIES, and EMBOSSED faces.

HIERATIC: Legros-1916.

HIEROGLYPHIC: Legros-1916.

HINDI: Legros-1916.

HIRA-GANA: Legros-1916.

Hitt-1960: See CODING symbols, and SYMBOLS.

HITTITE: Legros-1916.

Hodge-1962: See LEROY.

Hodge-1963: See LEROY.

Hogg-1957: See IRREGULAR symbols, SYMBOLS, and TYPEWRITER.

Hollingworth-1913: See BULLFINCH, CASLON, CENTURY, CENTURY OLD STYLE, CHELTENHAM, CUSHING MONOTYPE, CUSHING OLD STYLE, EXPANDED/EXTENDED/WIDE faces, IRREGULAR symbols, NEWS GOTHIC, SCOTCH ROMAN, and SYMBOLS.

HOMEWOOD: Longyear-1936.

Horton-1960: See TYPEWRITER.

Howell-1959: See MACKWORTH.

Howell-1961: See UNSPECIFIED EXPERIMENTAL faces.

Huey-1916: See FRAKTUR, SYMBOLS, and UNSPECIFIED COMMERCIAL faces.

Hughes-1961: See IRREGULAR symbols, SYMBOLS, and UNSPECIFIED COMMERCIAL and EXPERIMENTAL faces.

Hulbert-1957: See GOTHIC faces, IRREGULAR symbols, and SYMBOLS.

IBO: Legros-1916.

ICAO symbols: Whiteside-1951.

ICELANDIC: Legros-1916.

IDEAL: Tinker-1963, TinkPat-1943, and TinkPat-1944b.

IDEOGRAPH symbols: Legros-1916.

IEE: See Industrial Electronic Engineers.

ILLUSIONAL faces and forms: See OPTICAL ILLUSIONS.

IMPERIAL SCRIPT: Legros-1916.

IMPRINT: Burt-1959 and Poulton-1959.

IMPRINT OLD FACE: Pyke-1926 and Tinker-1963.

INCLINATION symbols: Crumley-1961, Legros-1916, and Swartz-1961.

INCLINED faces: See ITALICS.

INDICODER (display): Crumley-1961.

(Industrial Electronic Engineers) IEE (display): Crumley-1961.

INFOMAX (display): Deuth-1953, Long-1951, Long-1952a, Long-1952b, Long-1954, and Long-1955.

INITIALS (various): Legros-1916 and Longyear-1936.

INSCRIPTION GREEK: Legros-1916.

INSCRIPTION ROMAN: Legros-1916.

InsTUFTS-1952: See AMERICAN TYPEWRITER, ANTIQUE, BODONI, CASLON OLD STYLE, CHELTENHAM, GARAMOND, HANDWRITING, IRREGULAR symbols, ITALICS, KABEL, LIGHT faces, OLD ENGLISH, OLD STYLE, SCOTCH ROMAN, SCRIPT, and SYMBOLS.

(International Phonetic Association) IPA (printing): Legros-1916.

INTERSTATE (display): Smith-1958.

INTERTYPE 655: Tinker-1963 and TinkPat-1944b.

IONIC: Legros-1916, Paterson-1947a, Tinker-1963, TinkPat-1943, and TinkPat-1944b.

IOWA STATE (experimental): Lauer-1948.

IPA: See International Phonetic Association.

IRISH: Legros-1916.

IRREGULAR symbols (including FAMILIAR and GEOMETRIC forms, ARBITRARY shapes, PICTORIAL, ABSTRACT, and DISTORTED figures, etc. ---either LINE or SOLID): Berger-1960, Bowen-1959, Crook-1959, Crumley-1961, Hogg-1957, Hollingworth-1913, Hughes-1961, Hulbert-1957, InsTUFTS-1952, Kimura-1959, Klemmer-1958, Krzhivoglavy-1962, Lauer-1948, Legros-1916, Luckiesh-1923, Moore-1962, Rabinow-1962, Scott-1903, Sleight-1952, Starch-1914, Starch-1923, Tinker-1963, Ullman-1958, Utman-1963, Vernon-1948, and Webster-1963.

ITALIAN: Legros-1916.

ITALICS (including OBLIQUE faces and INCLINED/SLANT GOTHIC): ArmyWES-1953, Chapanis-1949, Chaundy-1954, InsTUFTS-1952, Legros-1916, Longyear-1936, Ovink-1938, Paterson-1940a, Poulton-1960, Starch-1914, Starch-1923, Tinker-1948c, Tinker-1952, Tinker-1953, Tinker-1955, Tinker-1963, TinkPat-1946b, TinkPat-1950, Vernon-1948, and Young-1946.

JAUNSARI: Legros-1916.

JAVANESE: Legros-1916.

JENSEN: Longyear-1936.

JENSEN OLD STYLE: Blackhurst-1927.

JENSON: Legros-1916.

KABEL: Chapanis-1949, InsTUFTS-1952, Longyear-1936, Paterson-1940a, Tinker-1944, Tinker-1963, and Young-1946.

BENGALI, BISAYA, BLACK, BLACKFRIARS, BLOCK style, BOHEMIAN, BOLD faces, BOOKLET, BORDER and BOTANICAL symbols, BRAILLE, BUGI, BULGARIAN, BURMESE, CARSHUNI, CARTOGRAPHIC and CHECKED symbols, CHECKERED TYPEWRITER, CHELTENHAM, CHELTENHAM OLD STYLE, CHEROKEE, CHINESE, CHINESE BRAILLE, CHIPPEWYAN, CIRCULAR symbols, CIVIL GEORGIAN, CLARENDON, COLUMBUS, COMMERCIAL symbols, COMPASS, CONDENSED faces, COPTIC, CORNER symbols, CREE, CROSS symbols, CUFIC, CUNEIFORM, DEMOTIC, DEVANAGARI, DE VINNE, DIACRITICAL MARKS, DUPLICATING MACHINE, ECCLESIASTICAL GEORGIAN, ECCLESIASTICAL symbols, EGYPTIAN, ELEMENT symbols, ELZEVIR, EMBOSSED faces, ENGINEERING symbols, ESKIMO, ESPERANTO, ESTIENNE MORSE, ESTRANGELO, ETHIOPIC, EXPANDED/EXTENDED/WIDE faces, FOURNIER, FRAKTUR, FRENCH, FRENCH ANTIQUE, FRENCH CLARENDON, GAELIC, GAME-COUNTER symbols, GAMMETER MULTIGRAPH, GENEALOGICAL symbols, GOTHIC, GOTHIC faces, GREEK, GROTESQUE, GROUNDWORK, GUARANI, GUJARATI, HADDON, HADDONIAN, HATCHED faces, HAWARDEN, HEBREW, HERALDIC symbols, HIERATIC, HIEROGLYPHIC, HINDI, HIRA-GANA, HITTITE, IBO, ICELANDIC, IDEOGRAPH symbols, ILLUSIONAL faces and forms, IMPERIAL SCRIPT, INCLINATION symbols, INITIALS, INSCRIPTION GREEK, INSCRIPTION ROMAN, IONIC, IPA, IRISH, IRREGULAR symbols, ITALIAN, JAUNSARI, JAVANESE, JENSON, KALMUK, KANA-MAJIRI, KANARESE, KERNED characters, KHOI-KHOI, KIENNING, KOREAN, LAO-TIAN, LATIN, LEPCHA, LIGATURES, LINE BRAILLE, LITHO-BLOCK, MAGYAR, MALAYALIM, MILISEET, MALTESE, MANCHU, MANUSCRIPT GREEK, MATHEMATICAL symbols, MATRIX/ELEMENT faces, MAYAN, MEDICAL and METEOROLOGICAL symbols, MIMAC, MODERN, MODERNIZED OLD STYLE, MODERN SYRIAC, MODIFIED faces, MONARCH, MONEY symbols, MONGOLIAN, MONOTYPE, MORLAND, MORSE TAPE, MUSIC symbols, NAMA, NEOSTYLE, NESTORIAN, NKONDI, NORWEGIAN, NSIBIDI, NO. FOUR, NO. SEVENTEEN, NO. TWENTY-THREE, NUPE, OLD ENGLISH, OLD FACE, OLD STYLE, OLD STYLE ANTIQUE, OLD TUDOR BLACK, OPTICAL ILLUSIONS, ORGANIZATIONAL symbols, ORIYA, ORNAMENTAL symbols, OUTLINE HIEROGLYPHIC, PALMYRENE, PARALLEL BAR symbols, PECULIARS, PESHITO, PHOENICIAN, PICA TYPEWRITER, PLAIN-SONG, POLISH, PUNJABI, RABBINICAL, REVERSED faces, ROAD SIGN symbols, RONALDSON, RONDE, RONEO, ROUMANIAN, RULE symbols, RUNIC, RUSSIAN, RUSSIAN CORPS 12, SAMARITAN, SANS, SANSERIF, SANS SERIF, SBIDIDI SCRIPT, SCHEUTZ, SCRIBAL abbreviations, SCRIPT, SCROLL symbols, SEMAPHORE, SEX symbols, SHORTHAND, SIAMESE, SINHALESE, SKELETON ANTIQUE, SLAVONIC, SLOVENIAN, SOL-FA, SPANISH, SWEDISH, SYMBOLS, SYRIAC, TAMIL, TELUGU, THAKURI, TIBETAN, TUDOR, TUDOR BLACK, TYPEWRITER, UNIVERSAL SYLLABICS, URDU, VENETIAN, VENETIAN OLD STYLE, WEIGHTS and MEASURES symbols, WELSH, WHEATSTONE PERFORATED RIBBON, WINCHELL, WINDSOR, XYLOGRAPHIC printing, YAHGAN, ZEND, and ZIG-ZAG symbols.

LEPCHA: Legros-1916.

LEROY (display): Bendix-1959, Crook-1954c, Foley-1957a, Harris-1956, Hodge-1962, Hodge-1963, Kuntz-1950, Swartz-1961, and Wright-1958a.

LIBERTY: Longyear-1936.

LIGATURES: Legros-1916.

LIGHT faces: ArmyWES-1953, Bendix-1959, Berger-1944b, Chapanis-1949, Foley-1957a, Foley-1957b, Gleason-1947, InsTUFTS-1952, Longyear-1936, Luckiesh-1940a, Luckiesh-1940b, Ovink-1938, Paterson-1940a, Tinker-1944, Tinker-1963, and Young-1946.

LINCOLN LABORATORY (display): Harris-1956 and Neisser-1960.

LINE BRAILLE: Legros-1916.

LINE symbols: Cohen-1953, Legros-1916, Swartz-1961, and also see IRREGULAR symbols, and SYMBOLS for other LINE figures.

LINE TRACE (display): Bjelland-(1963).

LINING GOTHIC: Bendix-1959 and Brown-1953.

LINING GROTESQUE: Pyke-1926 and Tinker-1963.

LINING METROTHIN: Bendix-1959.

LINING PLATE GOTHIC: Bendix-1959.

LINOTYPE TEXTYPE: Luckiesh-1942.

LINOTYPE NO. 2: Tinker-1963 and TinkPat-1944b.

Lippert-1962: See ALTERNATE GOTHIC and TYPEMASTER.

LIQUID MATRIX-CELL DISPLAY (display): Crumley-1961.

LITHO-BLOCK: Legros-1916.

LOCARNO: Ovink-1938.

Long-1951: See CONTROL INSTRUMENT COMPANY ELEMENT MATRIX, INFOMAX, MATRIX/ELEMENT faces, and 140- and 35-ELEMENT MATRIX.

Long-1952a: See CONTROL INSTRUMENT COMPANY ELEMENT MATRIX, INFOMAX, MATRIX/ELEMENT faces, and 140- and 35-ELEMENT MATRIX.

Long-1952b: See CONTROL INSTRUMENT COMPANY ELEMENT MATRIX, INFOMAX, MATRIX/ELEMENT faces, and 140- and 35-ELEMENT MATRIX.

Long-1954: See INFOMAX, and MATRIX/ELEMENT faces.

Long-1955: See INFOMAX, and MATRIX/ELEMENT faces.

Longyear-1936: See AMERICAN CASLON; ASTREE; BARNUM; BERNHARD CURSIVE, FASHION, and ROMAN; BETON; BINNEY; BODONI; BODONI BOOK and SHADED; BOLD faces; BOLD face SERIES; BOOKMAN; BRUCE; BRUCE OLD STYLE; BRUSH SCRIPT; CALIGRAPH; CASLON; CASLON MODERN and 540; CAXTON; CENTURY; CHARTER OAK; CHELTENHAM; CHELTENHAM OLD STYLE; CINCINNATI; CLEARCUT; CLEARFACE GOTHIC; CLOISTER; COCHIN-NICHOLAS; COLWELL; CONDENSED faces; COOPER; COOPER BLACK; COPPERPLATE GOTHIC; DELLA ROBBIA; DELPHIN; DUTCH; ELBAR; ENGRAVERS ROMAN; EVE; EXPANDED/ EXTENDED/WIDE faces; FRANKLIN GOTHIC; FUTURA; FUTURA DISPLAY; GALLEA; GARAMOND; GIRDER; GLORIA; GOTHIC faces; GOUDY; GOUDY CATALOGUE and HAND TOOLED; GRECO; GRECO ADORNADO; HOMEWOOD; INITIALS; ITALICS; JENSEN; KABEL; KARNAK; LIBERTY; LIGHT faces; LUCIAN; MANDATE; MAYFAIR; METROPOLIS; MISSALL; MODERN; MODERNIQUE; NEULAND; NEULAND INLINE; NEW CASLON; NOVELTY faces; NUBIAN; OLD STYLE; OPEN faces; ORPLID; PABST; PARISIAN; PARSONS; POST; PRISMA; PUBLICITY GOTHIC; RALEIGH CURSIVE; RECUT CASLON; REMINGTON TYPEWRITER; ROUND HAND; ROYCROFT; SCOTCH; SCOTCH ROMAN; SCRIPT; SHAKESPEARE; SIGNAL; SIGNAL BLACK; SPHINX; STYMIE; SWASHES; TOWER; TRAFTON SCRIPT; TYPO UPRIGHT; ULTRA BODONI; UMBA; VANITY; VERSATILE; VOGUE; WEBB INLINE; and ZEPPELIN.

Loucks-1944a: See DIVISION MARK symbols, SYMBOLS, and UNSPECIFIED

COMMERCIAL faces.

Loucks-1944b: See DIVISION MARK symbols, SYMBOLS, and UNSPECIFIED COMMERCIAL faces.

Loucks-1944c: See DIVISION MARK and POINTER symbols, SYMBOLS, and UNSPECIFIED COMMERCIAL faces.

Loucks-1944d: See DIVISION MARK symbols, SYMBOLS, and UNSPECIFIED COMMERCIAL faces.

LUCIAN: Longyear-1936.

Luckiesh-1923: See GOTHIC faces, IRREGULAR symbols, SCRIPT, and SYMBOLS.

Luckiesh-1937a: See MODERN GOTHIC, NEWSPAPER and NOVELTY faces, and OLD ENGLISH.

Luckiesh-1937c: See UNSPECIFIED COMMERCIAL faces.

Luckiesh-1940a: See BOLD and LIGHT faces, and MEMPHIS.

Luckiesh-1940b: See BODONI BOOK, BOLD faces, DE VINNE, LIGHT faces, and TEXTYPE.

Luckiesh-1941b: See CENTURY, EXPANDED/EXTENDED/WIDE faces, and TEXTYPE.

Luckiesh-1942: See BODONI, BOLD faces, BOOKMAN, CASLON OLD FACE, CENTURY, ELITE TYPEWRITER, EXCELSIOR, HANDWRITING, LINOTYPE TEXTYPE, MEMPHIS, METROLITE, OLD ENGLISH, PICA TYPEWRITER, SCOTCH ROMAN, SNELLEN, and TEXTYPE.

LUTETIA: Ovink-1938.

MACHINE RECOGNITION faces (machine recognition, magnetic and optical characters): Anderson-1960, Cohen-1953, Flores-1960, OptRead-1961, Rabinow-1954, Rabinow-1962, and Utman-1963.

MACKWORTH: Bendix-1959, Chapanis-1949, Colgate-(1955), Crook-1954c, Foley-1956, Harris-1956, Howell-1951, Krzhivoglavy-1962, Lansdell-1954, Mackworth-1944, Mackworth-1952, Murrell-1952, Murrell-1958, Schapiro-1952, and Swartz-1961.

Mackworth-1944: See MACKWORTH and RAID BLOCK.

Mackworth-1952: See MACKWORTH and RAID BLOCK.

MAGNETIC CHARACTER RECOGNITION: See MACHINE RECOGNITION faces.

MAGYAR: Legros-1916.

MALAYALIM: Legros-1916.

MALISEET: Legros-1916.

MALTESE: Legros-1916.

MANCHU: Legros-1916.

MANDATE: Longyear-1936.

MANUSCRIPT GREEK: Legros-1916.

MARAN GOTHIC: Bendix-1959.

MATHEMATICAL symbols: Chaundy-1954, Legros-1916, and Tinker-1963.

MONOTYPE: Legros-1916.

MONOTYPE GOTHIC: Crook-1952.

Moore-1958: See COURTNEY-FAA.

Moore-1962: See IRREGULAR symbols, SYMBOLS, and UNSPECIFIED COMMERCIAL faces.

MORLAND: Legros-1916.

MORSE TAPE: Legros-1916.

MOSAIC-STRUCTURE (display): Berger-1961.

MOUND: Lansdell-1954.

MS 33558: Bendix-1959, Swartz-1961, and also see AND 10400.

Murrell-1952: See BARTLETT, BERGER, MACKWORTH, and UNSPECIFIED COMMERCIAL faces.

Murrell-1958: See SCALE MARK symbols, and SYMBOLS.

MUSIC symbols: Legros-1916.

Nahinsky-1956: See UNSPECIFIED COMMERCIAL faces.

NAMA: Legros-1916.

NAMEL: Baker-1954, Bendix-1959, Squires-1957, and also see AMEL.

NARCISS: Ovink-1938.

NAVY GROW CHART: See GROW CHART.

Neisser-1960: See HANDWRITING and LINCOLN LABORATORY.

NEOSTYLE: Legros-1916.

NESTORIAN: Legros-1916.

NEULAND: Longyear-1936.

NEULAND INLINE: Longyear-1936.

NEW (experimental): Squires-1957.

NEW ANGULAR FORMS (experimental): Lansdell-1954 and also see LANSDELL.

NEW CASLON: Longyear-1936.

NEWS GOTHIC: Bendix-1959, Hollingworth-1913, Starch-1914, and Starch-1923.

NEWSPAPER faces (otherwise unspecified): Luckiesh-1937a.

NIXIE (display): Crumley-1961.

NKONDI: Legros-1916.

North-1951: See UNSPECIFIED COMMERCIAL faces.

NORWEGIAN: Legros-1916.

NOVELTY faces (otherwise unspecified): Bendix-1959, Legros-1916, Longyear-1936, Luckiesh-1937a, Ovink-1938, and Swartz-1961.

NSIBIDI: See SBIDIDI SCRIPT.

NUBIAN: Longyear-1936.

NO. TWO: Tinker-1963 and TinkPat-1944b.

NO. FOUR: Legros-1916.

NO. SEVENTEEN: Legros-1916.

NO. TWENTY-THREE: Legros-1916.

NUPE: Legros-1916.

OBLIQUE faces: See ITALICS.

OLD DANISH: Berger-1944b.

OLD ENGLISH: Bendix-1959, Burt-1959, Chapanis-1949, English-1944, InsTUFTS-1952, Legros-1916, Luckiesh-1937a, Luckiesh-1942, Paterson-1940a, Paterson-1947b, Poulton-1960, Starch-1923, Tinker-1944, Tinker-1963, TinkPat-1941, TinkPat-1950, and Young-1946.

OLD FACE: Legros-1916, Vernon-1931, and Vernon-1948.

OLD GERMAN: See FRAKTUR.

OLD ROMAN: See ROMAN.

OLD STYLE: Burt-1959, Chapanis-1949, InsTUFTS-1952, Legros-1916, Longyear-1936, Paterson-1940a, Poulton-1960, Pyke-1926, Swartz-1961, Tinker-1944, Tinker-1963, TinkPat-1944b, Vernon-1931, and Young-1946.

OLD STYLE ANTIQUE: Legros-1916, Pyke-1926, and Tinker-1963.

OLD TUDOR BLACK: See OLD ENGLISH.

OMEGA: Ovink-1938.

OPEN style (otherwise unspecified): Aldrich-1937, Bendix-1959, and Longyear-1936.

OPTICAL CHARACTER RECOGNITION (otherwise unidentified): Utman-1963, and also see MACHINE RECOGNITION faces.

OPTICAL ILLUSIONS: Legros-1916.

OPTICON: Tinker-1963, TinkPat-1943, and TinkPat-1944b.

OptRead-1961: See DIACRITICAL MARKS, ELITE GOTHIC, MACHINE RECOGNITION faces, SELFCHEK, SYMBOLS, and TYPEWRITER.

ORDNANCE: Crook-1954c and Swartz-1961.

ORGANIZATIONAL symbols: Legros-1916.

ORIYA: Legros-1916.

ORNAMENTAL faces: Bendix-1959.

ORNAMENTAL symbols: Legros-1916.

ORPHEUS: Ovink-1938.

ORPLID: Longyear-1936.

OUTLINE HIEROGLYPHIC: Legros-1916.

OVAL style (otherwise unspecified): Crook-1954c.

Ovink-1938: See ARPKE, BEMBO, BERNHARD CURSIVE and ROMAN, BETON, BODONI,

BOLD faces, COLUMBIA, CONDENSED faces, DE VINNE, ECKMANN, EXCELSIOR, EXPANDED/EXTENDED/WIDE faces, GALLIA, GOTHIC faces, GRASSET, ITALICS, KERNED characters, KONTRAST, LIGHT faces, LOCARNO, LUTETIA, MEDIAEVAL, METROPOLIS, MODERN, NARCISS, NOVELTY faces, OMEGA, ORPHEUS, ROMAANSCH, SAECULUM, SCRIPT, SHADOW NOBEL, THANNHAUSER, TRAFTON SCRIPT, and UNSPECIFIED COMMERCIAL and EXPERIMENTAL faces.

PABST: Longyear-1936.

PALMYRENE: Legros-1916.

PARAGON: Tinker-1963, TinkPat-1943, and TinkPat-1944b.

PARALLEL BAR symbols: Berger-1960, Gleason-1947, and Legros-1916.

PARISIAN: Longyear-1936.

PARK AVENUE: Flores-1960.

PARSONS: Longyear-1936.

Paterson-1940a: See AMERICAN TYPEWRITER, ANTIQUE, BODONI, BOLD faces, CASLON, CHELTENHAM, GARAMOND, GRANJON, ITALICS, KABEL, LIGHT faces, OLD ENGLISH, OLD STYLE, and SCOTCH ROMAN.

Paterson-1940b: See SCOTCH ROMAN.

Paterson-1942a: See SCOTCH ROMAN.

Paterson-1942b: See SCOTCH ROMAN.

Paterson-1943: See GRANJON.

Paterson-1944: See SCOTCH ROMAN.

Paterson-1946a: See BOLD faces, CHELTENHAM, and MEMPHIS.

Paterson-1947a: See IONIC.

Paterson-1947b: See OLD ENGLISH and SCOTCH ROMAN.

PECULIARS: Legros-1916.

PERPETUA: Burt-1959.

Perry-1962: See PICA TYPEWRITER.

PESHITO: Legros-1916.

PHILADELPHIA LINING: Bendix-1959.

PHOENICIAN: Legros-1916.

PHOTOTYPE: Bendix-1959.

PICA: Melville-1957.

PICA TYPEWRITER (printing): Legros-1916, Luckiesh-1942, and Perry-1962.

PICTORIAL figures: See IRREGULAR symbols.

PLAIN-SONG: See MUSIC symbols.

PLANTIN: Burt-1959.

PLATE GOTHIC: Bendix-1959.

POINTER symbols: Gleason-1947, Loucks-1944c, and Spragg-1952.

SHAPED BEAM (display): Bjelland-(1963).

SHORTHAND: Legros-1916.

SIAMESE: Legros-1916.

SIGNAL: Longyear-1936.

SIGNAL BLACK: Longyear-1936.

Silver-1940: See EMBOSSED and UNSPECIFIED COMMERCIAL faces.

SINHALESE: Legros-1916.

SKELETON ANTIQUE: Legros-1916.

SLANT faces: See ITALICS.

SLAVONIC: See ANCIENT SLAVONIC.

Sleight-1952: See CIRCULAR, CROSS, DIAMOND, ELLIPTICAL, IRREGULAR, RECTANGULAR, SQUARE, and STAR symbols; SYMBOLS; and TRIANGULAR symbols.

Slivinske-1957: See AND 10400.

SLOVENIAN: Legros-1916.

SMALL-FACE: Scott-1903.

Smith-1958: See ARROW symbols, CALIFORNIA, INTERSTATE, and SYMBOLS.

SNELLEN: Lauer-1948 and Luckiesh-1942.

Soar-1955a: See CENTURY, HANDWRITING, and UNSPECIFIED EXPERIMENTAL faces.

Soar-1955b: See BROWN, and EMBOSSED faces.

Soar-1958: See BROWN, McLAUGHLIN, and UNSPECIFIED EXPERIMENTAL faces.

SOL-FA: See MUSIC symbols.

SOLID figures: See IRREGULAR symbols, and SYMBOLS.

Solomon-1956: See BPR SERIES.

SPANISH: Legros-1916.

SPARTAN: Bendix-1959, Rowland-1958, Tinker-1963, and TinkPat-1944b.

SPARTAN BLACK: Bendix-1959.

SPARTAN BOOK: Bendix-1959.

SPHINX: Longyear-1936.

Spragg-1952: See POINTER and SCALE MARK symbols, SYMBOLS, and UNSPECIFIED COMMERCIAL faces.

SQUARE GOTHIC: Bendix-1959 and Rowland-1958.

SQUARE symbols: Bowen-1959, Lauer-1948, and Sleight-1952.

Squires-1957: See NAMEL and NEW.

STANFORD RESEARCH (machine recognition): Flores-1960.

Starch-1914: See BOLD faces, BULLFINCH, CASLON, CENTURY, CENTURY OLD STYLE, CHELTENHAM, CONDENSED faces, CUSHING MONOTONE and OLD STYLE, EXPANDED/EXTENDED/WIDE faces, FRAKTUR, IRREGULAR symbols,

ITALICS, NEWS GOTHIC, OLD ROMAN, SCOTCH ROMAN, and SYMBOLS.

Starch-1923: See BODONI, BOLD faces, BULLFINCH, CASLON, CENTURY, CENTURY OLD STYLE, CHELTENHAM, CHELTENHAM OLD STYLE, CONDENSED faces, CUSHING MONOTONE and OLD STYLE, EXPANDED/EXTENDED/WIDE faces, HANDWRITING, IRREGULAR symbols, ITALICS, NEWS GOTHIC, OLD ENGLISH, SCOTCH ROMAN, and SYMBOLS.

STAR symbols: Casperson-1950 and Sleight-1952.

STRIPE symbols: Decker-1961.

STYMIE: Longyear-1936.

SUB- and SUPER-SCRIPTS: Chaundy-1954.

Swartz-1961: See AMEL; AND 10400; BERGER; COLOR symbols; CRAIK; DOT, ELLIPTICAL, and INCLINATION symbols; LANSDELL; LEROY; LINE symbols; MACKWORTH; MATRIX/ELEMENT faces; MODERN; MS 33558; NOVELTY faces; OLD STYLE; ORDNANCE; ROMAN; SYMBOLS; and 6- and 8-ELEMENT, STRAIGHT-LINE MATRIX.

SWASHES: Longyear-1936.

SWEDISH: Legros-1916.

SYMBOLS (various): Bauch-1954, Berger-1960, Bowen-1959, Brainard-1961, Casperson-1950, Chaundy-1954, Cohen-1953, Crook-1959, Crumley-1961, Decker-1961, Gleason-1947, Gustafson-1960, Halsey-1960b, Hitt-1960, Hogg-1957, Hollingworth-1913, Huey-1916, Hughes-1961, Hulbert-1957, InsTUFTS-1952, Kimura-1959, Klemmer-1958, Krzhivoglavy-1962, Lauer-1948, Legros-1916, Loucks-1944a, Loucks-1944b, Loucks-1944c, Loucks-1944d, Luckiesh-1923, Moore-1962, Murrell-1958, OptRead-1961, Pyke-1926, Rabinow-1962, Scott-1903, Sleight-1952, Smith-1958, Spragg-1952, Starch-1914, Starch-1923, Swartz-1961, Tinker-1963, Ullman-1958, Utman-1963, Vernon-1948, Webster-1963, Whiteside-1951, and also see specific symbol types.

SYRIAC: See MODERN SYRIAC.

TAMIL: Legros-1916.

TELEREGISTER (display): Crumley-1961.

TELUGU: Legros-1916.

TEMPO: Bendix-1959 and English-1944.

TEXTYPE: Luckiesh-1940b, Luckiesh-1941b, Luckiesh-1942, Tinker-1963, TinkPat-1943, and TinkPat-1944b.

THAKURI: Legros-1916.

THANNHAUSER: Ovink-1938.

TIBETAN: Legros-1916.

TIMES NEW ROMAN: Burt-1959 and Poulton-1959.

TIMES ROMAN: Vernon-1948.

Tinker-1944: See AMERICAN TYPEWRITER, ANTIQUE, BODONI, CASLON OLD STYLE, CHELTENHAM, GARAMOND, KABEL, LIGHT faces, OLD ENGLISH, OLD STYLE, and SCOTCH ROMAN.

Tinker-1945: See UNSPECIFIED COMMERCIAL faces.

Tinker-1946: See EXCELSIOR.

Tinker-1948a: See UNSPECIFIED COMMERCIAL faces.

Tinker-1948b: See EXCELSIOR.

Tinker-1948c: See EXCELSIOR and ITALICS.

Tinker-1952: See EXCELSIOR and ITALICS.

Tinker-1953: See EXCELSIOR and ITALICS.

Tinker-1954: See EXCELSIOR.

Tinker-1955: See EXCELSIOR and ITALICS.

Tinker-1957: See SCOTCH ROMAN.

Tinker-1960: See EXCELSIOR.

Tinker-1963: See AMERICAN TYPEWRITER, ANTIQUE, BODONI, BOLD faces, CASLON, CENTURY, CHELTENHAM, CLASSIC, CONDENSED faces, CORONA, CUSHING, DE VINNE, EXCELSIOR, EXPANDED/EXTENDED/WIDE faces, GARAMOND, GRANJON, HANDWRITING, IDEAL, IMPRINT OLD FACE, INTERTYPE 655, IONIC, IRREGULAR symbols, ITALICS, KABEL, LIGHT faces, LINING GROTESQUE, LINOTYPE NO. 2, MATHEMATICAL symbols, MERGENTHALER NO. 2, MODERN, NO. 2, OLD ENGLISH, OLD STYLE, OLD STYLE ANTIQUE, OPTICON, PARAGON, REGAL, ROMAN, SCOTCH ROMAN, SCRIPT, SPARTAN, SYMBOLS, TEXTYPE, and TYPEWRITER.

TinkPat-1941: See OLD ENGLISH and SCOTCH ROMAN.

TinkPat-1942: See SCOTCH ROMAN.

TinkPat-1943: See CENTURY, EXCELSIOR, EXPANDED/EXTENDED/WIDE faces, IDEAL, IONIC, OPTICON, PARAGON, REGAL, and TEXTYPE.

TinkPat-1944a: See SCOTCH ROMAN.

TinkPat-1944b: See ANTIQUE, BODONI, CENTURY, CHELTENHAM, CLASSIC, CORONA, DE VINNE, EXCELSIOR, IDEAL, INTERTYPE 655, IONIC, LINOTYPE NO. 2, MERGENTHALER NO. 2, MODERN, NO. 2, OLD STYLE, OPTICON, PARAGON, REGAL, ROMAN, SPARTAN, and TEXTYPE.

TinkPat-1946a: See EXCELSIOR.

TinkPat-1946b: See BOLD faces, EXCELSIOR, ITALICS, and MEMPHIS.

TinkPat-1949: See SCOTCH ROMAN.

TinkPat-1950: See ITALICS, OLD ENGLISH, TYPEWRITER, and UNSPECIFIED COMMERCIAL faces.

TOURIST: Bendix-1959.

TOWER: Longyear-1936.

TRADITIONAL GOTHIC: See OLD ENGLISH.

TRAFTON SCRIPT: Longyear-1936 and Ovink-1938.

TRIANGULAR faces: Bendix-1959.

TRIANGULAR symbols: Bowen-1959, Casperson-1950, and Sleight-1952.

TUDOR: See OLD ENGLISH.

TUDOR BLACK: See OLD ENGLISH.

TWENTIETH CENTURY: Bendix-1959 and Deuth-1953.

TYPEMASTER (various): Bendix-1959 and Lippert-1962.

TYPEWRITER (otherwise unspecified): Dearborn-1906, Dearborn-1951, Dodge-1907, Hogg-1957, Horton-1960, Legros-1916, Mecherikoff-1959, OptRead-1961, Rabinow-1962, Tinker-1963, TinkPat-1950, and Webster-1963, and Young-1946.

TYPO UPRIGHT: Longyear-1936.

Uhlaner-1941: See BLOCK style.

Ullman-1958: See BPR SERIES, COLOR and IRREGULAR symbols, and SYMBOLS.

ULTRA BODONI: Longyear-1936.

UMBA: Longyear-1936.

UNION (display): Crumley-1961.

UNIVERSAL SYLLABICS: Legros-1916.

UNO PEN STENCIL (display): Foley-1957b.

UNSPECIFIED COMMERCIAL faces (various): Bendix-1959, Bitterman-1945, Bitterman-1946a, Bitterman-1946c, Carmichael-1947, Crook-1947a, Crook-1947b, Crook-1950a, Erdmann-1898, Gleason-1947, Huey-1916, Hughes-1961, Kimura-1959, Klare-1957, Klare-1963, Lauer-1948, Loucks-1944a, Loucks-1944b, Loucks-1944c, Loucks-1944d, Luckiesh-1937c, Mead-1954, Moore-1962, Murrell-1952, Nahinsky-1956, North-1951, Ovink-1938, Silver-1940, Spragg-1952, Tinker-1945, Tinker-1948a, TinkPat-1950, and Vernon-1931.

UNSPECIFIED EXPERIMENTAL faces (various): AmASHO-1961, Bendix-1959, Berger-1961, Botha-1963b, Brown-1953, Case-1952, Craik-1943, Crook-1954c, Dixon-1948, Flores-1960, Forbes-1951, Gleason-1947, Howell-1961, Hughes-1961, Karmeier-1960, Lauer-1948, Ovink-1938, Soar-1955a, Soar-1958, and Webster-1963.

URDU: Legros-1916.

Utman-1963: See CMC7, E13B, IRREGULAR symbols, MACHINE RECOGNITION faces, OPTICAL CHARACTER RECOGNITION, and SYMBOLS.

VANITY: Longyear-1936.

VARIGRAPH: Crook-1954a and Crook-1954b.

VARITYPE: Bendix-1959.

VENETIAN: Legros-1916.

VENETIAN OLD STYLE: Legros-1916.

VERMONT 1937 (display): Aldrich-1937.

VERNEN: Bendix-1959.

Vernon-1931: See BASKERVILLE, BODONI MODERN, CASLON, GOTHIC faces, HANDWRITING, MODERN FACE, MODERN STYLE, OLD FACE, OLD STYLE, SCRIPT, and UNSPECIFIED COMMERCIAL faces.

Vernon-1948: See CLARENDON, GREEK, IRREGULAR symbols, ITALICS, OLD FACE, SYMBOLS, and TIMES ROMAN.

VERONESE: Burt-1959.

VERSATILE: Longyear-1936.

VIDEOGRAPH (display): Crumley-1961.

VIDIAC (display): Crumley-1961.

VOGUE: Bendix-1959, Brown-1953, and Longyear-1936.

WALBAUM: Burt-1959.

Warren-1942: See BOLD faces, CHELTENHAM, CONDENSED faces, and MEMPHIS.

WEBB INLINE: Longyear-1936.

WEIGHTS and MEASURES symbols: Legros-1916.

WEISS: Berger-1956.

WELSH: Legros-1916.

WHEATSTONE PERFORATED RIBBON: Legros-1916.

Whiteside-1951: See ICAO and RAF symbols, and SYMBOLS.

WIDE faces: See EXPANDED/EXTENDED/WIDE faces.

WINCHELL: Legros-1916.

WINDSOR: Legros-1916.

WRICO (display): ArmyWES-1953.

Wright-1958a: See LEROY.

Wright-1958b: See AMEL and AND 10400.

XEROGRAPHIC PRINTER: Crumley-1961.

XYLOGRAPHIC printing: Legros-1916.

YAHGAN: Legros-1916.

Young-1946: See AMERICAN TYPEWRITER, ANTIQUE, BODONI, CHELTENHAM, ITALICS, KABEL, LIGHT faces, MODERN, OLD ENGLISH, OLD STYLE, and SCOTCH ROMAN.

ZEND: Legros-1916.

ZEPPELIN: Longyear-1936.

ZIG-ZAG symbols: Legros-1916.

140-ELEMENT MATRIX (experimental): Long-1951, Long-1952a, Long-1952b, and also see INFOMAX.

2 MILLIMETER STROKE-WIDTH (experimental): Berger-1944b and also see BERGER.

35-ELEMENT MATRIX (experimental): Long-1951, Long-1952a, Long-1952b, and also see INFOMAX.

5 X 7 MATRIX (various): Bauer-1962, Halsey-1960a, and Rabinow-1954.

6-ELEMENT, STRAIGHT-LINE MATRIX (display): Alluisi-1958 and Swartz-1961.

6 MILLIMETER STROKE-WIDTH (experimental): Berger-1944b and also see BERGER.

7-SEGMENT (display): Klemmer-1958.

8-ELEMENT, STRAIGHT-LINE MATRIX (display): Alluisi-1957 and Swartz-1961.

* * *

# APPENDIX C: CHARACTER FACE SAMPLES

## CHARACTER FACE SAMPLES

The Character Face Samples are intended to illustrate some of the varieties of alphanumeric characters and other symbols which have been used in the legibility experimentation. The applications for these characters range from book text and automobile license plates to automatic character recognition for back checks and cathode ray tube (CRT) displays for air traffic control. Standards and specifications have been developed for labeling, dial faces and other applications in military systems and equipment.

Anyone desiring an introduction to the many type faces used for foreign languages should refer to: von Ostermann, George F., "Manual of Foreign Languages." New York: Central Book Company, Inc., 1952, 414 p., Fourth Edition, Revised and enlarged.

Most printers keep a library of type face sample books. These books show the wide variety of type faces which are commercially available.

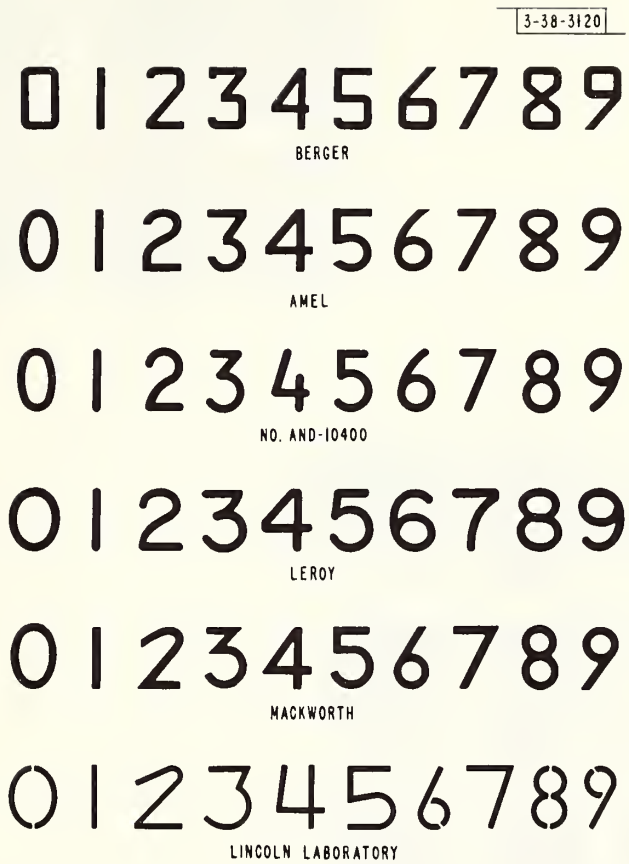
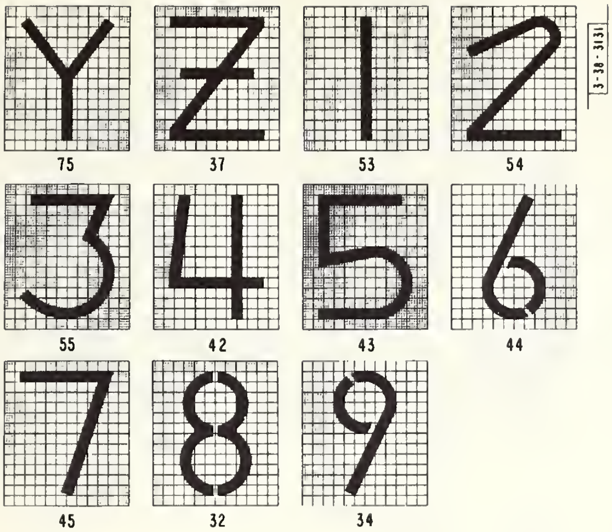



Plate 1. Numeral designs studied for cathode ray tube presentation (from Harris-1956).


Plate 2. Design for Charactron (cathode ray tube) characters (M. I. T. Mod X), A-X (from Harris-1956).



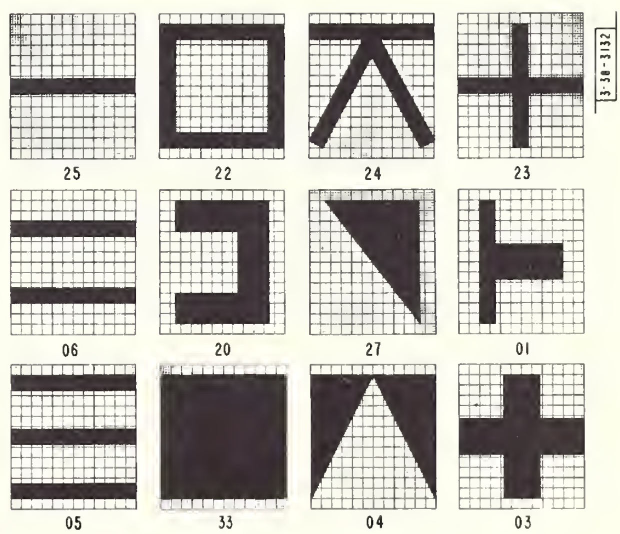
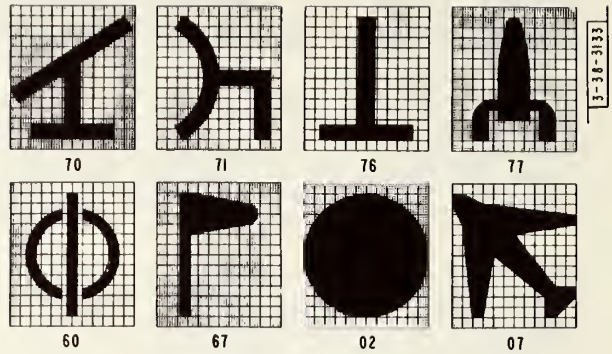




Plate 3. Design for Charactron (cathode ray tube) characters (M. I. T. Mod X), Y-Z, 1-9, and related symbols (from Harris-1956).



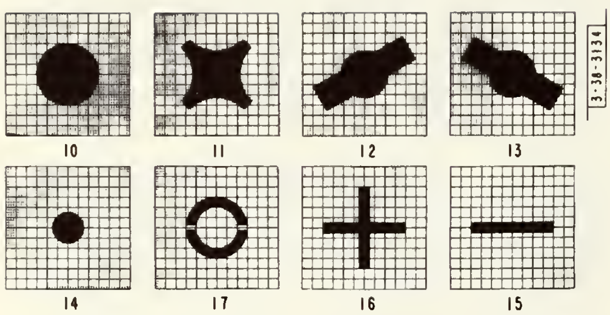




Plate 4. Design for Charactron (cathode ray tube) characters (M. I. T. Mod X), special symbols and radar-data symbols (from Harris-1956).

A B C D E F G

H I J K L M N

O P Q R S T U

V W X Y Z

0 1 2 3 4 5

6 7 8 9

NUMERALS AND LETTERS SHALL CONFORM TO THOSE SHOWN ON THIS DRAWING.

UNLESS OTHERWISE SPECIFIED, THE RATIO OF HEIGHT TO WIDTH OF LINE SHALL BE 8 TO 1 EXCEPT NUMERALS AND LETTERS 1/8 INCH HIGH AND UNDER SHALL BE NOT LESS THAN 6 TO 1.

FOR DETAIL DIMENSIONS, SEE THE DETAIL INSTRUMENT SPECIFICATION.

(A) PROVISIONS OF THIS STANDARD ARE THE SUBJECT OF INTERNATIONAL STANDARDIZATION AGREEMENTS. WHEN AMENDMENT, REVISION OR CANCELATION OF THIS STANDARD IS PROPOSED, THE DEPARTMENTAL CUSTODIANS WILL INFORM THEIR RESPECTIVE DEPARTMENTAL STANDARDIZATION OFFICE SO THAT APPROPIATE ACTION MAY BE TAKEN RESPECTING THE INTERNATIONAL AGREEMENT CONCERNED.

THIS IS A DESIGN STANDARD, NOT TO BE USED AS A PART NUMBER.

APPROVED 4 Feb 55 REVISED (A) 17 Dec 57

| CUSTODIANS | OTHER INT. | MILITARY STANDARD | MS33558 (ASG) |
|---|---|---|---|
| Navy-BuAer<br>Air Force | A -<br>N -<br>AF -<br>INTERNAT. | NUMERALS AND LETTERS, AIRCRAFT INSTRUMENT DIAL, STANDARD FORM OF | |
| Procurement Specification<br>None | | SUPERSEDES: AND10400 | SHEET 1 OF 1 |

NOTICE: When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Plate 5. Example of a U. S. Military Standard for numerals and letters.

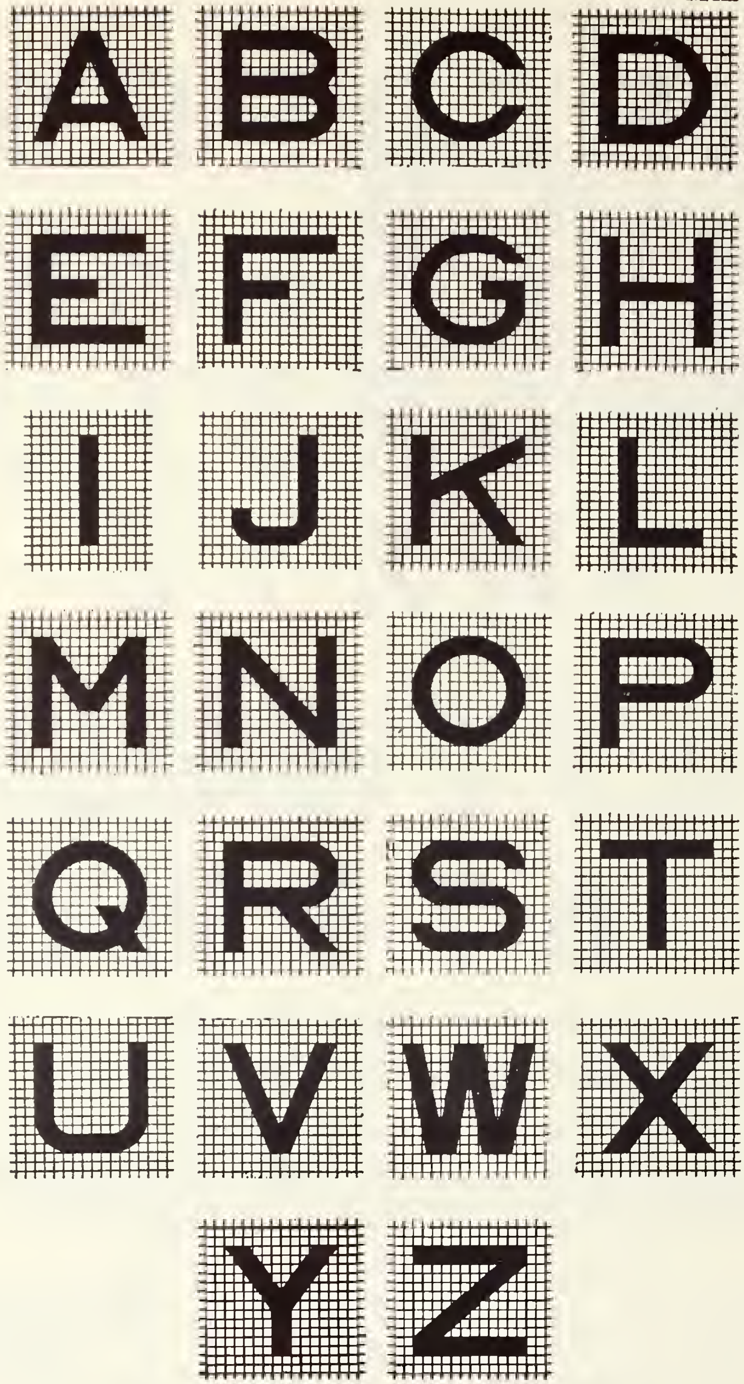



Plate 6. The letter font required by U.S. Military Specification No. MIL-M-18012B, dated 20 July 1964, Design and Configuration of Markings for Aircrew Station Displays.

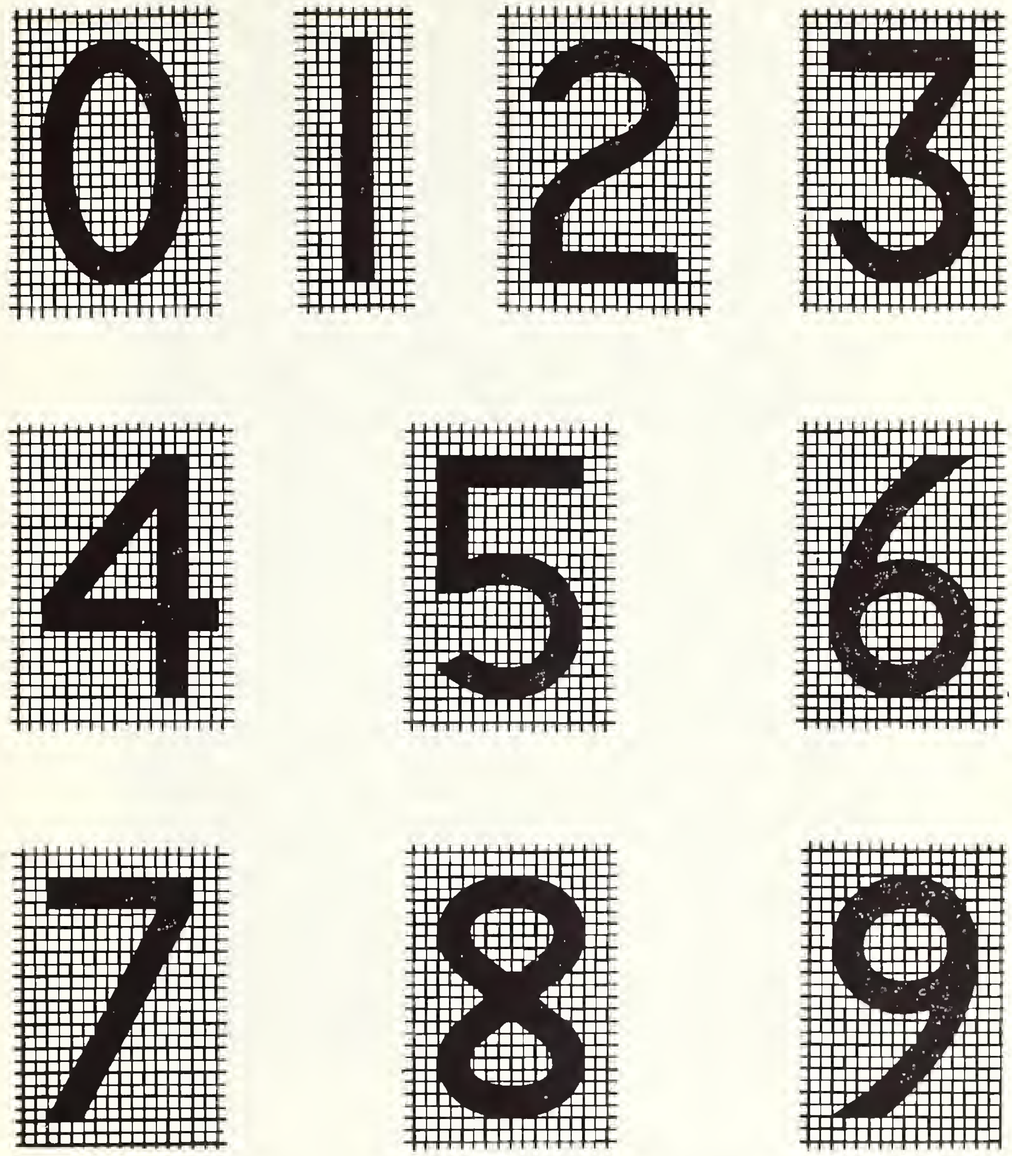


Plate 7. The numeral font required by U.S. Military Specification No. MIL-M-18012B, dated 20 July 1964, Design and Configuration of Markings for AircrewStation Displays.


Plate 8. Final best choice selection of commercially available type styles (Letters-Memphis Bold; Numbers-Spartan Bold Italic), used in a closed circuit television experiment (from Rowland-1958).

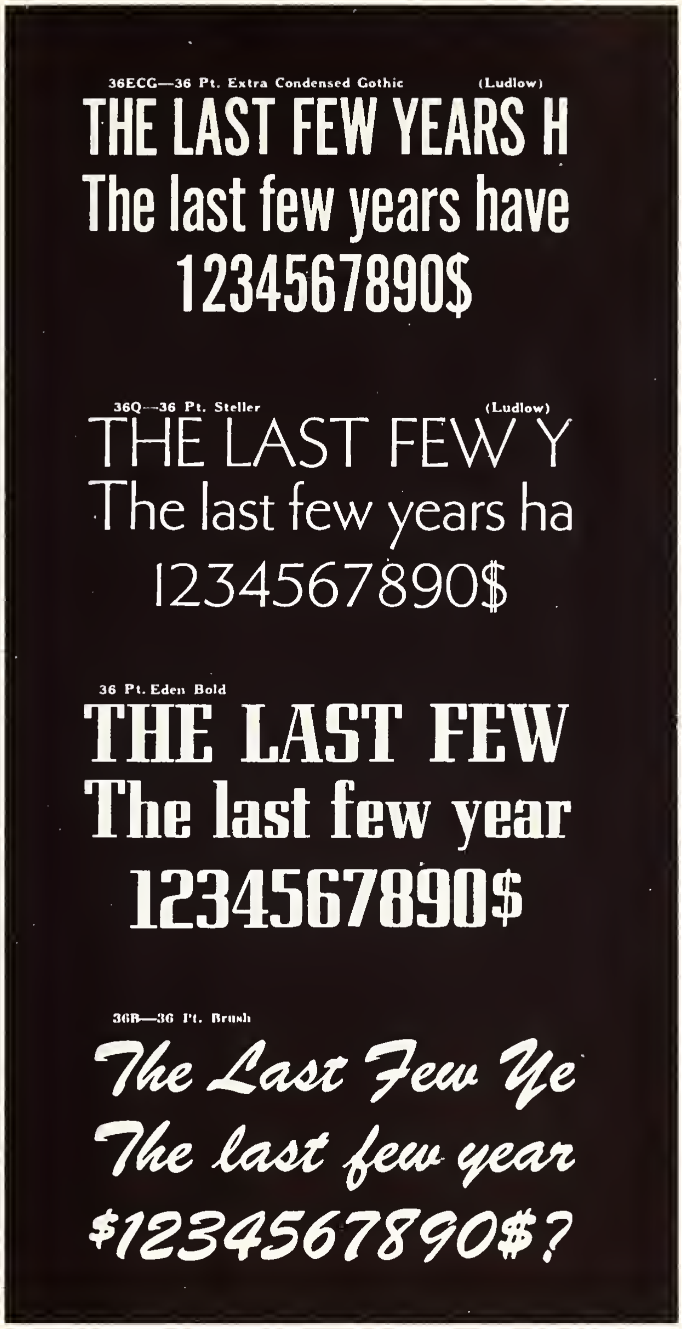



Plate 9. Examples of commercial type styles which were tested and considered unsatisfactory for television-type display (from Rowland-1958).

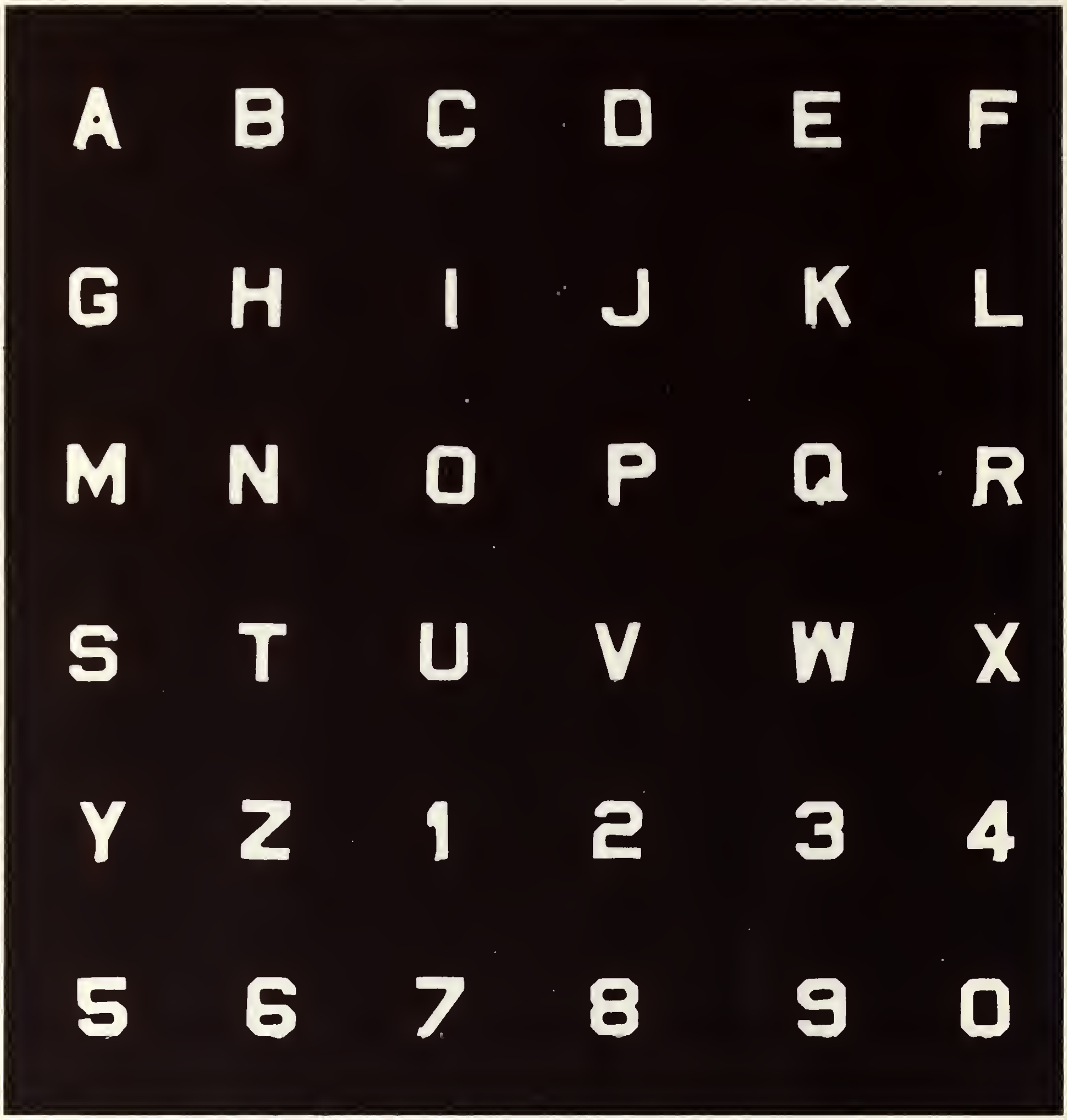



Plate 10. Restaurant menu characters used for closed circuit television display experimentation (from Rowland-1958).

Plate 11a. Experimental alphanumeric characters tested for closed circuit television display purposes (A-L), (from Rowland-1958).


Plate 11b. Experimental alphanumeric characters tested for closed circuit television display purposes (M-X), (from Rowland-1958).

Plate 11c. Experimental alphanumeric characters tested for closed circuit television display purposes (Y-Ø), (from Rowland-1958).


Plate 12. Complete set of alphanumeric characters finally selected as a result of closed circuit television display experimentation. (Caution-evaluate only on an actual TV, raster-type, display), (from Rowland-1958).

# APPENDIX D: GLOSSARY OF MATRIX INDEX TERMS

## GLOSSARY OF MATRIX INDEX TERMS

The Matrix Index Terms and their descriptions in this Glossary indicate the criteria used for selection and entry into the Matrix, Subject Index. It must be noted that these descriptions were determined on a subjective basis, that is to say, they were determined on the basis of representing commonality of the various aspects of the legibility problem, as it was seen in the documents extracted for this Handbook. Therefore, the Glossary descriptions are neither exhaustive in describing the aspect involved, nor do they represent general, dictionary-type definitions of the Terms.

## ENVIRONMENT - Presentation

text: the main body of matter on a printed or written page, including short notes and other continuous material usually viewed at the normal reading distance of approximately 14 inches (e.g. reference books).

opaque display: any display of characters and symbols, other than text, that are designed for viewing in an ambient light environment and in which neither print nor background are transparent, translucent, or "reflective" (e.g. non-reflective highway signs).

luminous display: any display of characters and symbols, other than text, in which either print or background or both are translucent, transparent, self-illuminated, or optically reflective (e.g. cathode-ray tube displays).

graphic display: text or display of any kind that includes or is in the form of charts, maps, geometric forms, or other non-character content (e.g. aircraft navigation charts).

consoles & panels: character, symbol, color, or geometric form displays designed for viewing in a control or indicator situation, especially one in which the display is input to, output from, or an indicator of the status of an operational situation (e.g. computer consoles).

signs & labels: primarily character or symbol displays of an identification or static nature (e.g. name-plates identifying various dials and controls in an aircraft cockpit).

other: any type of display or character/symbol presentation other than those delineated above (e.g. newspaper headlines).

## ENVIRONMENT - Illumination

variable: a situation in which illumination is varied in intensity, direction, source, and/or color while all other parameters are held constant.

unusual: for the viewing situation considered, any type of illumination used that is not normally encountered in a comparable real viewing situation.

colored: illumination, external to the stimulus, that is other than the color usually attributed to a source (i.e. blue-white or white for fluorescent, or yellow-white for incandescent lamps).

trans/luminous: applies to situations in which the light source is either trans-illuminated through or generated by the stimulus or its immediate background.

## ENVIRONMENT - Background

contrast amount: the difference in brightness, reflectance, or hue between the character/ symbol and its immediate background.

colors: the use or presence of chromatics on the stimulus background.

surface features: situations in which the characteristics of the stimulus background are either unusual or variable (e.g. glossy vs. matte paper).

contrast direction: the condition of either reversing the contrast direction between the stimulus and its immediate background (e.g. black on white vs. white on black), or the use of an abnormal direction for a normal situation (e.g. white print on black background for text reading).

## ENVIRONMENT - Viewing Conditions

reading distance: a distance normally used for the reading or viewing of continuous text or other types of documents viewed within a person's arm reach (i.e. 14 to 27 inches for continuous text).

console distance: any distance that is either at or somewhat beyond arm's reach and that is normally encountered in the "control display" rather than the static or distant display situation.

distance $>$ c. 25': ascribed to those viewing situations in which the display, for the purpose of this Handbook, is located at a distance greater than about 25 feet (e.g. highway signs).

variable distances: experimental or real situations in which all other conditions are held constant while the distance at which a stimulus is viewed is varied either dynamically or in steps.

variable angles: describes situations in which a stimulus is viewed from some angle other than normal (i.e. 90 degrees) from the orientation plane of the stimulus.

## ENVIRONMENT - Noise

environmental: any condition in the viewing environment that does or could degrade the subject's viewing performance (e.g. mechanical vibration, ambient light flicker, acoustic noise, parallax error, etc.).

stimulus/subject: any condition in the stimulus or subject that tends to degrade viewing performance (e.g. blur, glare, stimulus errors, halo effects, fatigue, ocular defects, perceptual span limitations, optical illusions, etc.).

## TYPOGRAPHY - Characters

alphabetic: characters that are or could be used to form continuous text (e.g. A to Z in English), but including also the special case of Roman Numerals.

numeric: non-alphabetic characters used to represent quantitative values, specifically 0 through 9 in Arabic Notation.

symbolic: characters or geometric representations other than alphabetic or numeric notations, but intended for use in the same context (e.g. $, *, =, diacritical marks, etc.).

capitals: those alphabetic characters of the upper case, especially with reference to their exclusive use in continuous text (e.g. a computer print-out), or as single stimuli.

combined cases: the use of both upper and lower cases in the same context (e.g. continuous text).

lower case: the use of lower case alphabetic characters either singly or in context.

## TYPOGRAPHY - Faces

commercial: alphabetic and numeric faces that are commercially available in some type of printing medium (e.g. lead type, photo-composing templates, acetate overlays, etc.).

experimental/symbolic: non-standard, not commercially available, and usually specially devised alphabetic, numeric, or symbolic faces developed for experimental purposes.

government: those faces developed for, and specified for use in governmental or public situations (e.g. MS 33558, BPR Series, etc.).

foreign: any printing or display faces that utilize characters, numerals, symbols, or diacritical marks not found in English usage.

machine generated: those characters and symbols generated by or in some type of mechanical and/or electronic device (e.g. typewriters, character generating cathode-ray tubes, etc.).

drafting: characters and symbols generated by the use of pen and template (e.g. Leroy, Wrico, etc.).

hand-written/-printed: characters and symbols printed or written by a person without the use of mechanical aids.

machine recognition: those characters and symbols, generated by any means, for the distinct purpose of being optically or magnetically read by some type of automatic recognition device.

## TYPOGRAPHY - Face Designs

visual angle: the angle, at the eye, subtended by the stimulus being viewed --- specified when this angle is variable, unusual, or used in such a way as to simulate one viewing distance by the use of another.

height: ascribed to variations in or significance of the height of a character or symbol.

width: ascribed to variations in or significance of the width of a character or symbol.

stroke-width: ascribed to variations in or significance of the actual or mean width of stroke of a character or symbol.

height : width: significance of or variations in the ratio of character/symbol height to width (e.g. condensed vs. expanded faces).

height : stroke-width: significance of or variations in the ratio of character/symbol height to its actual or mean width of stroke (e.g. thin vs. bold faces).

configuration: significance of or variations in the design of a character (e.g. seriffed vs. sansserif characters, in-line vs. filled characters, etc.).

colors: the use of chromatics in the printing or display of character/symbol faces.

luminosity: the quality of the character/symbol face generating or amplifying illumination (e.g. Nixie tube numerals, electroluminescent characters, trans-illuminated characters, beaded or reflectorized characters, etc.).

## TYPOGRAPHY - Layout

character orientation: as a significant factor or as a variable, the orientation of a character or symbol relative to its normally viewed upright position (e.g. upside-down).

character spacing: as a significant factor or as a variable, the distance between characters or symbols in text or other type of display in either an absolute or relative sense.

grouping: as a significant factor or as a variable, the association of alphabetic, numeric, and/or symbolic characters by position, number, or type of mixture, as in studies of license plate character combinations.

word/line length: as an absolute or relative variable, consideration of the horizontal width of a word or group of words (e.g. as measured in picas or inches for a printed line of text).

vertical line spacing: the vertical distance (leading or interlineage) between characters, words, or lines of print (e.g. as measured in points for letterpress text), when this distance was considered to be either significant or variable.

margins/borders: where significant, unusual, or variable, the presence, absence, and size of "white space" around a character grouping to set it off from its background --- including any type of ornamental or symbolic device, such as a black line, designed to enclose the text or character grouping.

emphasis (various): any device utilized to regroup characters or text into separate units (e.g. double-column printing on a page), draw attention to a display (as with arrows and pointers), make the content easier to read (e.g. by paragraphing), or draw attention to specific characters, words, or groups of words (as by underlining, italicizing, coloning, etc.).

other considerations: any other layout or formatting considerations, when significant, variable, or unusual, that bear on the legibility of the display (e.g. the position of an advertisement on a page).

## STUDY CONTENT - Basic Functions

readability: considerations involving recognition of the information content of meaningful material, when this material is represented by groups of alphabetic characters in word, sentence, or continuous text form.

recognizability: considerations involving the recognition of individual characters, either singly or as part of a set, with some statistical significance of certainty that the character is specifically identified.

perceptibility: considerations involving the recognition of text or display as consisting of character(s), with some basic recognition as to whether they may be alphabetic, numeric, or symbolic; and possibly that they might be read without explicit recognition of individual characters.

visibility: considerations involving interference (between stimulus and observer) in recognizing the presence or absence of a character or character set.

## STUDY CONTENT - Type of Article

experiment: those studies in which the content represents the design and/or result of an empirical investigation into the human legibility of characters and/or symbols.

development/design: those studies in which the content represents the attempt or accomplishment of the development/design of character(s) for use in either improving their legibility or adapting them to an unusual viewing situation --- includes also the design of humanly legible characters for automatic character recognition.

standard: the promulgation of a specific character/symbol set when its use is mandatory or voluntarily agreed upon in specific situations (e.g. the MS 33558 alphabet for military displays).

review: those studies which contain reference to, information about, and/or recommendations about past, present, and future research and development in some specific area of the legibility of characters and symbols.

## STUDY CONTENT - Results

statistical: studies in which, usually out of empirical research, the results are statistically evaluated.

subjective: studies in which the discussions and results are other than those designed for statistical evaluation (e.g. a compilation of type-face designs).

## EXPERIMENTAL FUNCTIONS - Presentation

reading/viewing: all types of experimental presentations other than tachistoscopic.

tachistoscopic: any type of experimental presentation involving a relatively short exposure (usually less than 0.1 second) of the stimulus to the subject.

## EXPERIMENTAL FUNCTIONS - Subjects

large N ($\geq$ 30): experimental situations in which the number of subjects utilized is 30 or more.

small N ($<$ 30): experimental situations in which the number of subjects utilized is less than 30.

## EXPERIMENTAL FUNCTIONS - Response Types

comprehension: an experimental basis for response by a subject in which it is his task to comprehend the meaningful content of material in which the stimulus characters appear.

comparison: an experimental basis for response by a subject in which it is his task to compare the stimulus with a control (e.g. to determine whether it is the same or different).

recognition: an experimental basis for response by a subject in which it is his task to identify a character or symbol to the exclusion of all others.

## EXPERIMENTAL FUNCTIONS - Response Functions

verbal: an experimental situation involving an oral response by a subject to stimuli.

motor: an experimental situation in which the subject responds to stimuli by performance of some bodily motor function (e.g. pushing a button, pulling a lever, etc.).

clerical: an experimental situation in which the subject responds to stimuli by mentally translating it into another function (e.g. crossing out letters, adding numbers mentally and registering them into an adding machine, etc.).

eye movements: an experimental situation in which subject response is recorded by the experimenter through his measurement of such things as blink-rate, pupil size, fixation frequency, etc.

## EXPERIMENTAL FUNCTIONS - Test Criteria

accuracy: statistical evaluation of subject responses usually stated in terms of error rate.

speed: statistical evaluation of subject responses as to either the number of responses per unit time or the total number of responses for a pre-set time.

threshold: statistical evaluation of subject responses as measured by the quantity of units required to give a 50-50 probability of recognition (or some other measure) of the stimulus (e.g. nearness of stimulus to the subject, amount of light required to recognize the stimulus, number of words read on either side of a fixation point, etc.).

other: statistical evaluation of any other type of physical (e.g. symbol tracking performance) or psycho-physical (e.g. heart rate or nervous muscular tension) response by a subject.

* * *

# THE NATIONAL BUREAU OF STANDARDS

The National Bureau of Standards[1] provides measurement and technical information services essential to the efficiency and effectiveness of the work of the Nation's scientists and engineers. The Bureau serves also as a focal point in the Federal Government for assuring maximum application of the physical and engineering sciences to the advancement of technology in industry and commerce. To accomplish this mission, the Bureau is organized into three institutes covering broad program areas of research and services:

**THE INSTITUTE FOR BASIC STANDARDS** . . . provides the central basis within the United States for a complete and consistent system of physical measurements, coordinates that system with the measurement systems of other nations, and furnishes essential services leading to accurate and uniform physical measurements throughout the Nation's scientific community, industry, and commerce. This Institute comprises a series of divisions, each serving a classical subject matter area:

—Applied Mathematics—Electricity—Metrology—Mechanics—Heat—Atomic Physics—Physical Chemistry—Radiation Physics—Laboratory Astrophysics[2]—Radio Standards Laboratory,[2] which includes Radio Standards Physics and Radio Standards Engineering—Office of Standard Reference Data.

**THE INSTITUTE FOR MATERIALS RESEARCH** . . . conducts materials research and provides associated materials services including mainly reference materials and data on the properties of materials. Beyond its direct interest to the Nation's scientists and engineers, this Institute yields services which are essential to the advancement of technology in industry and commerce. This Institute is organized primarily by technical fields:

—Analytical Chemistry—Metallurgy—Reactor Radiations—Polymers—Inorganic Materials—Cryogenics[2]—Materials Evaluation Laboratory—Office of Standard Reference Materials.

**THE INSTITUTE FOR APPLIED TECHNOLOGY** . . . provides technical services to promote the use of available technology and to facilitate technological innovation in industry and government. The principal elements of this Institute are:

—Building Research—Electronic Instrumentation—Textile and Apparel Technology Center—Technical Analysis—Center for Computer Sciences and Technology—Office of Weights and Measures—Office of Engineering Standards Services—Office of Invention and Innovation—Clearinghouse for Federal Scientific and Technical Information.[3]

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[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D. C., 20234.

[2] Located at Boulder, Colorado, 80302.

[3] Located at 5285 Port Royal Road, Springfield, Virginia, 22151.

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LEGIBILITY OF ALPHANUMERIC CHARACTERS & OTHER SYMBOLS

A MATRIX, SUBJECT INDEX TO SELECTED, ANNOTATED LITERATURE

DOUGLAS Y. CORNOG AND F. CLAYTON ROSE

NATIONAL BUREAU OF STANDARDS